

ELECTRICITY GENERATING AUTHORITY OF THAILAND



INVITATION FOR BIDS NO. EGAT 8/2568-LTK2-H1

LAMTAKONG HYDROPOWER PROJECT

VOLUME II

TECHNICAL SPECIFICATIONS - EQUIPMENT WORKS

ELECTRICITY GENERATING AUTHORITY OF THAILAND

LAMTAKONG HYDROPOWER PROJECT

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TECHNICAL GENERAL SPECIFICATIONS

LAMTAKONG HYDROPOWER PROJECT
TECHNICAL GENERAL SPECIFICATIONS

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TG - TECHNICAL GENERAL SPECIFICATIONS

TG-1 GENERAL

1.1 These specifications apply to all equipment, materials, devices and components, including pre-engineered or bought-out items, procedures, methods, techniques, and workmanship contained in the other Technical Specifications whether referred to specifically or not.

1.2 Where the other Technical Specifications conflict with these specifications, the former shall prevail.

1.3 All works shall be subject to a quality control program developed by the Contractor which shall be designed to prevent and readily detect and correct non-conformities in quality of the work as specified in Clause SC-4.2, or internationally recognized equivalent. The Contractor shall make available to the Engineer details of the quality control program at the Contractor's and sub-Contractors plants which are applicable to the work before manufacturing begins. (For quality control standard of material and workmanship refer to Clause GC 13).

1.4 The Engineer will be the sole judge of material and workmanship, among other things, finished and supplied by the Contractor. No patching, plugging, shimming or other such means to overcome defects, discrepancies or errors shall be employed without the written agreement of the Engineer. Failure to comply with this requirement shall constitute grounds for rejection of the item in question.

1.5 Material and equipment not covered by these Specifications shall be subject to acceptance by the Engineer.

Document and equipment numbering system

The document numbering system provides details related to the Project, the relevant Contract, document type, work item, major component, sequence number and revision numbers.

All document sequence numbers shall be requested from and provided by the respective designated Document Controller.

Table 1: Example Structure of Document Number

LTK2-H1-AAA-BB-C-DDD-0000-A0						
Field1	Field2	Field3	Field4	Field5	Field7	Field8
LTK2-H1	AAA	BB	C	DDD	0000	A0
Project	Contractor	Document type	Work item	Major component	Sequence Number	Revision number

The identification system for power stations KKS (Kraftwerks-Kennzeichen-System) shall be assigned for the complete power plant and its components and provides a format code language for the powerplant's owner, operators and asset manager.

The identification code shall consist of a maximum of 4 breakdown levels:

breakdown level	0	1	2	3
Process-related identification	Total plant	System designation	Equipment	Component
Point of installation identification				
Location identification				

A handbook of the Document and the KKS system with the meaning and designated field content described shall be made by the Contractor. The guideline shall be easy to understand, an example to illustrate the breakdown level shall be made. The Contractor shall present his standard design to EGAT during the design stage.

TG-2 SERVICE CONDITIONS

All the equipment shall be designed and manufactured for its particular location for continuous operation at the extremes of climate as listed in Clause LC-6. Specifically, all equipment to be installed indoors shall be designed and manufactured for satisfactory continuous operation at an ambient temperature of 40°C and all equipment to be installed outside shall be designed and manufactured for satisfactory continuous operation at an ambient temperature of 45°C. Equipment supplied between ceilings and roofs shall be designed for satisfactory operation at an ambient temperature of 60°C.

TG-3 STANDARDS AND CODES

3.1 Except as provided in the specifications, all materials, equipment and fabrication and testing thereof shall conform to the latest applicable standards contained in the following list of internationally accepted standards.

- Aluminum Association
- Anti-Friction Bearing Manufacturers Association (AFBMA)
- American Concrete Institute (ACI)
- American Gear Manufacturers Association (AGMA)
- Association of Iron and Steel Engineers (AISE)
- American Institute of Steel Construction (AISC)
- American Iron and Steel Institute (AISI)
- Air Moving and Conditioning Association (AMCA)
- American National Standards Institute (ANSI)
- American Society of Mechanical Engineers (ASME)
- American Society for Testing and Materials (ASTM)

- American Welding Society (AWS)
- American Water Works Association (AWWA)
- International Special Committee on Radio Interference (CISPR)
- Crane Manufacturers Association of America (CMAA)
- Diesel Engine Manufacturers Association (DEMA)
- European Standard (EN)
- Factory Mutual Engineering Corporation (FM)
- Hoist Manufacturers Institute (HMI)
- International Electrotechnical Commission (IEC)
- Institute of Electrical and Electronics Engineers, Inc. (IEEE)
- Insulated Cable Engineers Association (ICEA)
- International Organization for Standardization (ISO).
- National Electrical Code (NEC) (ANSI/NFPA 70)
- National Electrical Manufacturers Association (NEMA)
- National Fire Protection Association (NFPA)
- National Plumbing Code (ANSI A40.8)
- Society of Automotive Engineers, Inc. (SAE)
- Sheet Metal and Air Conditioning Contractors' National Association, Inc. (SMACNA)
- Steel Structures Painting Council (SSPC)
- Underwriters' Laboratories Inc. (UL)
- United States Bureau of Reclamation (USBR) (Water and Power Resources Service in the US Department of the Interior)

3.2 References to standards or to materials and equipment of a particular manufacturer shall be regarded as followed by the words “or equivalent”. The Contractor may propose alternative standards, materials or equipment, which shall be equivalent to those specified. If the Contractor for any reason proposes alternatives to or deviations from the above standards, or desires to use materials or equipment not covered by the above standards, the Contractor shall state the exact nature of and the reason for making the change with his Bid. The Contractor

shall submit to the Engineer, for approval, a comparison of applicable clauses of the proposed standard with the specified and relevant specifications of the materials and equipment in the original language and in English language. The Engineer's decision in the matter of equality will be final.

TG-4 UNITS OF MEASUREMENT

4.1 Units of measurement shall be in the international system of units (SI), using the following abbreviations.

Quantity	Unit	Symbol	Remarks
Length	millimeter	Mm	
	meter	m	
Time	Second	S	
	Hour	H	
	Day	D	
	minute	min	
Area	square meter	m ²	
Volume	Liter	L	
	cubic meter	m ³	
Temperature	Degree	°C	
	Celsius		
Force	Newton	N	
	kilo-Newton	kN	
Pressure or Stress	Newton per square meter	N/m ²	
	or Pascal	Pa	
Mass	Kilogram	Kg	
	or tonne	t	
Density	Kilogram per cubic meter	kg/m ³	
Impact Strength or Torque	joules or Newton-meter	J, N-m	
Moment of Inertia	kilogram square meter	kg-m ²	
Power	watt	W	
Frequency	hertz	Hz	
Electric Potential	volt	V	
Electric Resistance	ohm	Ω	
Electric Current	ampere	A	

4.2 The following is a list of prefixes used in conjunction with the basic units.

Multiplying Factor	Prefix	Symbol
10 ⁹	giga	G
10 ⁶	mega	M
10 ³	kilo	k
10 ⁻² centi	c	
10 ⁻³ milli	m	
10 ⁻⁶ micro	μ	

TG-5 CONTROL AND AUXILIARY POWER SUPPLIES

5.1 The following power supplies will be provided in the powerhouse, switchyard and control area. The equipment shall be suitable for operation on these supplies as applicable.

- a. dc control voltage 48 V (nominal)
- b. Power supply for motor drives and large power requirements: 400 V, three-phase, 50 Hz ac supply (nominal)

TG-6 STATION SERVICE POWER

The station service power is supplied with three-phase, 4-wire, 50-Hz, 400/230 V ac. All electrical equipment and apparatus, which will receive power from station service circuits, shall withstand voltage and frequency fluctuation of $\pm 10\%$ and $\pm 15\%$, respectively with a maximum transient frequency of $\pm 40\%$, all in the same direction simultaneously.

TG-7 MATERIALS

7.1 Materials for the equipment, which are not included in these specifications, shall be selected after thoroughly scrutinizing the properties thereof and shall be subject to approval by the Engineer. The materials shall be of good quality and as usually used for equipment of the same kind.

7.2 All specified mill tests, including impact tests for pressure-containing work, shall be performed for each carbon steel plate to be used in the manufacture of the work.

7.3 Materials shall conform to the following requirements.

(a) Castings

The materials for each kind of casting shall be in accordance with the following.

- Iron castings - ASTM A48, Class 30 or better
- Carbon steel castings - ASTM A27, Grade 65-35 or better
- Stainless steel castings - ASTM - specification number, grade and composition shall be submitted to the Engineer for approval

All castings shall be true to pattern, of workmanlike finish, and of uniform quality and condition, free from injurious blowholes, porosity, hard spots, shrinkage defects, cracks or other defects as determined by visual inspection, and shall be satisfactorily cleaned for their intended purpose. The surfaces of castings which do not undergo machining, particularly those in contact with water, shall be dressed smooth with all joints blended into adjacent surfaces. They shall be free from foundry irregularities such as projections, ridges, hollows, honeycombing, pock marks or chip marks so that they will not require surface smoothing operations prior to painting. All defects shall be fully explored and castings shall not be repaired, plugged or welded without written permission from the Engineer. Such permission will be given only when the defects are small and do not adversely affect the strength, use or machinability of the castings.

Any excessive segregation of impurities or alloys in a casting may be cause for its rejection. Large fillets compatible with the design shall be incorporated wherever a change in section occurs. Chaplets located at or near the bolting flanges as of a turbine runner crown will not be permitted. The casting mold and casting practice shall be designed to minimize the occurrence of hot tears or shrinkage cavities. Casting molds shall be designed to allow free contraction upon cooling to minimize the occurrence of high stresses caused by the mold or chills. The design of the casting mold and the casting practice to be employed in producing runner casting(s) shall be forwarded to the Engineer for information.

For all runner castings, a chemical analysis shall be taken and reported at the time of tapping and pouring. The time of tapping and pouring shall be recorded. Temperatures of tapping and pouring shall also be observed and reported, as well as the time of removal of the casting from the mold. This information shall be supplied to the Engineer at the time of inspection.

Test coupons from which test specimens are prepared shall be attached to all castings of mass 250 kg or more. The number, size and location of the test coupons shall be recorded, and the records made available to the Engineer on request.

The tests required for turbine runner castings shall be as follows.

Mass of Castings	Number of Tension Tests	Number of Bend Tests
Not over 9 t	Three-120 apart	2
Over 9 but not over 14 t	Three-120 apart	2
In excess of 14 t	Four - 90 apart	2

For castings of mass 250 kg or less, one tension and one bend test shall be required.

Bend tests shall be made on specimen 25 mm by 15 mm in cross-section with corner radii not exceeding 2 mm. They shall withstand being bent cold around a pin 25 mm in diameter and through an angle of 90 without cracking on the outside of the bent portion.

The Engineer will inspect castings of all principal parts, including all parts subject to hydraulic pressure such as the runner and guide vanes, at the foundry. The inspection will be during and after cleaning and removal of defects, but prior to any repair welding. No steel casting shall be finally heat treated before inspection without the permission of the Engineer. Castings will also be inspected after repairs, heat treatment and during machining. No major welding shall be carried out after the casting is finally heat-treated.

Magnetic particle (MT) and dye penetrant (PT) inspection and acceptance criteria shall be in accordance with the ASME Boiler and Pressure Vessel Code, Appendixes 6 and 8.

Radiographic inspection (RT) and standards of acceptability of steel castings up to 50.8 mm thick shall be in accordance with ASTM E446, high-pressure castings and for steel castings 50.8 to 114 mm thick, ASTM E186.

Ultrasonic inspection (UT) and standards of acceptability for steel casting shall be to ASTM E 114. Any discontinuities whose reflections do not exceed a height equal to 20%

of the normal back reflection or do not increase reflection during movement of the transducer 50 mm in any direction, shall be considered acceptable. Indications exceeding these limits shall be repaired.

Runner casting(s) shall be subject to complete PT or MT and UT throughout the areas of the interconnection between the blades and band, and blades and crown for a distance of 250 mm either side of the fillets. For MT inspection, a current of 1000 A and prod spacing of no more than 150 mm shall be used. Prior to performing this inspection the surfaces shall be prepared to the extent necessary to assure that inspection is thorough and permits precise interpretation. The runner shall also be inspected in detail over the area surrounding the main shaft bolting flanges and the exterior of the band.

Casting repair welds shall be carried out in accordance with ASTM standards and approved welding procedures, and no repair welds in excess of 20mm depth will be permitted without stress relieving unless otherwise agreed by the Engineer.

Repair welding on steel castings, other than repair welding of minor defects, shall be done by the metallic arc process followed by thermal stress relieving. Repair of 13-4 stainless steel castings shall be carried out with low carbon electrodes of the same chemical composition as the parent material. Minor repairs of hollows, shallower than 5 mm, may be carried out with low carbon austenitic stainless steel electrodes. Repair procedures must be submitted to the Engineer, and reviewed, before repairs are made. Repaired areas shall be re-inspected with MT or PT.

Repair welding on iron castings shall not be permitted.

All steel castings, which, in operation, will be as revolving parts shall be given a double heat treatment. In each treatment the casting shall be held at the desired temperature for a sufficient time to ensure the proper grain refinement throughout the casting. Such castings shall be furnace cooled after the final treatment.

The heat-treating furnace shall be equipped with a sufficient number of recording pyrometers, accurately calibrated, to ensure full information regarding temperatures and uniformity of heat treatment. Where castings have a section of 150 mm or more in thickness, thermocouples shall be placed in holes drilled in dummy blocks of section equal to the heaviest part of the casting. The Engineer shall have access to the pyrometer charts, at the time inspection is made, for purposes of record and for checking the annealing. When requested, a complete report of the entire heat treatment shall be furnished to the Engineer.

(b) Forgings

Shaft forgings and all other forgings shall be in accordance with ASTM A668, Class D or better. Alloy forgings shall have physical properties at least equal to those required by ASTM A668 Class H.

The largest fillets compatible with the design shall be incorporated wherever a change in section occurs. Tool marks for tearing of the metal by the finishing tool will not be permitted on the surface of fillets. Grinding or polishing shall be required to remove such marks if they occur. All finished surfaces or forgings shall be smooth and free from tool marks.

Ingots from which the forgings are made shall be cast in metal molds. The workmanship shall be first class in every respect, and the forgings shall be free from all defects affecting their strength and durability, including seams, pipes, flaws, cracks, scales, fins, porosity, hard spots, excessive nonmetallic inclusions and segregation's.

Forging of all principal parts including all parts subject to hydraulic pressure will be inspected at the forging plant in the ingot stage, and after forming, cleaning and removal of defects. Forgings will also be inspected after repairs, heat treatment, and machining have been completed.

All forgings shall be given such uniform heat treatments as are required to produce materials conforming to the requirements of these specifications. All forgings, however, shall be annealed, or normalized and drawn, as final heat treatments. In the case of shafts forged solid which are required to be bored, the final heat treatments, i.e., annealing, or normalizing and drawings, shall be performed after the forging has been rough bored.

The Engineer shall have access to the pyrometer charts covering the heat treatments. A record of the heat treatments to which the forgings have been submitted shall be supplied to the Engineer on request.

Forgings shall be clearly stamped with the heat number in such location as to be readily legible when the forging is assembled in a complete unit.

Test coupons shall be provided in accordance with ASTM A370, unless otherwise specified.

Shafts 3 m or more in length of 4500 kg or more in mass, shall have a prolongation left at both ends of the forging.

Unless otherwise agreed three tension and one bend test specimens shall be taken in a longitudinal direction from the part of the forging which includes the top part of the ingot as cast, and two tension specimens shall be taken from the other end of the forging. The above specimens shall be taken midway between the center and outside machine-finished diameter of the shaft for solid forgings, and midway between the inner and outer machine-finished diameter of the shaft for bored forgings.

Bend test shall be made on a specimen 25 mm by 15 mm in cross-section, with corner radii not exceeding 2 mm. They shall withstand being bent cold around a pin 25 mm in diameter through 180 without cracking on the outside of the bent portion.

All forgings for shafts shall be subject to metallographic examination of the test specimens taken therefrom, and acceptance shall depend on the results of this examination as well as the physical characteristics of the material as determined by the tensile and bend tests.

The metallographic requirements shall be as follows.

- The specimens, when examined at a magnification of 100X, shall show a homogeneous structure in which the normal constituents are evenly distributed, free from decided segregation of any constituents, ingotism or excessive impurities.

Where shafts are forged in multiple from a single ingot, (i.e., forged in one piece and machined apart), tests on each shaft need not be made, the tests from the individual forging being adequate.

If the results of the physical tests do not conform to the requirements specified, further heat treatment may be carried out, in which case re-tests shall be made as specified above. Should any test specimen fail due to defective machining or because of flaws, it may be discarded and another substituted, provided the defect causing failure is not sufficiently extensive to impair the value of the forging.

(c) Steel Plate for Pressure Vessels, Penstock, Bifurcation and Spiral case

Steel plate used for principal stress-carrying parts shall meet ASTM A516, unless otherwise specified.

All carbon steel plates for pressure-containing work shall be subject to Charpy V-notch, impact tests in accordance with ASTM A370. The test shall have a minimum impact strength of 20 J for an average of 3 samples tested at 0°C, with no one sample having less than 13.6 J impact strength.

(d) Stainless Steel

Stainless steel, if not specifically specified, shall be in accordance with appropriate ASTM specification or better. The grade, specification number and chemical composition shall be submitted to the Engineer for approval.

(e) Bronze and Brass Bushings

Bronze for guide vane bushings matched with stainless steel sleeves shall be in accordance with ASTM B 584, Alloy No. C93700, C86300, C90500 or approved equivalent. Rods shall be to ASTM B 21, Alloy A, half-hard except for special applications (e.g., shear pins) which shall be to the Contractor's design. Bronze and brass for other purposes shall be submitted to the Engineer for approval.

(f) Self-Lubricating Bearing

Self-lubricating bearings shall be of the type successfully used for respective application intended, such as "Thordon", "Fiberglide" or accepted equivalent. Austenitic stainless steel washers, pins or slide paths for operation in conjunction with self-lubricating bearings, unless otherwise specified, shall be included. Surface finish, hardness, tolerance of fit and other details of the mating surface shall be in accordance with best recommended practice of the bearing supplier.

(g) Babbitt

Babbitt metal for bearings shall be in accordance with ASTM Specification B23, Alloy No. 7.

(h) Metals

When it is necessary to use dissimilar metals in contact, these shall, if possible, be so selected that the potential difference between them in the electrochemical series is not

greater than 0.5 V. If this is not possible, the contact surfaces of one or both of the metals shall be electroplated or otherwise finished in such a manner that the potential difference is reduced to within the required limits. If practicable, the two metals shall be insulated from each other by an approved insulating material or a coating of approved varnish compound.

(i) Screws, Nuts, Springs, Pivots, etc

The use of iron and steel shall be avoided in instruments and electrical relays wherever possible. Steel screws, when used, shall be zinc, cadmium or chromium plated, or when plating is not possible owing to tolerance limitations, shall be of stainless steel. The threads of stainless steel fastenings shall be coated with a suitable anti-galling compound at time of assembly.

All wood screws shall be of dull nickel-plated brass or of other approved finish. Instrument screws (except those forming part of a magnetic circuit) shall be of brass or bronze. Springs shall be of non-rusting material, e.g., phosphor bronze or nickel silver, as far as possible.

All screws, bolts, studs and nuts for the turbine parts shall be in accordance with ASTM A193 or equivalent in European standards (EN) depending on the material grade.

(j) Fabrics, Cork, Paper, etc

Fabrics, cork, paper and similar materials, which are not subsequently to be protected by impregnation, shall be adequately treated with an approved fungicide. Sleevings and fabrics treated with linseed oil or varnishes shall not be used.

(k) Wood

The use of wood in equipment shall be avoided so far as possible. When used, woodwork is to be thoroughly seasoned teak or other approved wood which is resistant to fungal decay and shall be free from shakes and warp, sap and wane, knots, faults and other blemishes. All woodwork shall be suitably treated to protect it against the ingress of moisture and from the growth of fungus and termite attack, unless it is naturally resistant to those causes of deterioration. All joints in woodwork shall be dovetailed or tongued and pinned as far as possible. Metal fittings where used shall be of nonferrous material.

(l) Adhesives

Adhesives are to be specially selected to ensure the use of types which are impervious to moisture, resistant to mold growth, and not subject to the ravages of insects. Synthetic resin cement only shall be used for joining wood. Casein cement shall not be used.

(m) Gaskets and Compounds

Neoprene and similar synthetic compounds, not subject to deterioration due to the climatic conditions, shall be used for gaskets, sealing rings, diaphragms, etc, instead of the standard rubber-based materials.

(n) Mechanical Protection

All Plant shall be designed to prevent ingress of vermin, dust and dirt. Where wiring, piping or ductwork passes through openings in equipment housing, such openings shall be constructed to prevent ingress of vermin. Wiring and piping enclosures and ductwork shall also be vermin proof.

TG-8 ALLOWABLE STRESSES

8.1 Liberal factors of safety which make allowance for higher than anticipated loading shall be used throughout the design, particularly in the design of all parts subject to alternating or impact loading.

8.2 For the rotating parts of the turbine, generator and exciter, the maximum unit stress due to runaway speed conditions shall not exceed two thirds (2/3) of the minimum specified yield stress of the material, except as permitted below. Stresses shall be further reduced in accordance with good practice for parts subject to severe loading conditions and/or shall be further reduced on components where elastic stability governs and where combined stresses exist.

8.3 For operation at runaway speed with maximum head, the allowable stresses may be increased, but they shall not exceed two third (2/3) of the minimum specified yield strength of the material.

8.4 For material subject to the specified water pressure, including surge, and for all other material subjected to specified operating conditions, including load rejection and load acceptance, the unit stress in the material shall not exceed the values in the following tabulation.

Material	Maximum Unit Stress	
	In Tension (MPa)	In Compression (MPa)
Cast iron	14	70
Cast steel	70	70
Plate steel for pressure vessels, penstock, bifurcation and spiral case	ASME Boiler and Pressure Vessel Code, Section VIII, Division I, latest edition	

8.5 Non-specified material shall have a maximum stress of one quarter (1/4) the minimum specified ultimate tensile strength as given for the appropriate material specification.

8.6 Allowable stresses for non-pressurized parts of plate steel shall not exceed the values of the AISC Specifications for the Design, Fabrication and Erection of Structural Steel for Buildings, latest edition.

8.7 For all parts subject to water pressure, including surge, a 2-mm increase in plate thickness is required as a corrosion allowance.

8.8 Minimum thickness of any pressure carrying plate in contact with water shall be 8 mm.

TG-9 GENERAL EQUIPMENT REQUIREMENTS

9.1 The equipment and all manufactured components thereof shall be new, durable to withstand long time use, and shall satisfy all requirements which a complete product should generally meet even if such are not expressly provided for in these specifications.

PVC, plastic, rubber or materials which will be degraded by sunlight shall be avoided for outdoor equipment.

9.2 Where the technical specifications call for supply of instrumentation, controls or electrical devices, the Contractor shall provide suitable enclosures conforming to TG-10. All devices pertinent to equipment operation or monitoring shall be mounted on the face of such enclosures.

9.3 The equipment shall be of construction safe and conveniently for disassembly - assembly, inspection, accessibility, erection and also for maintenance and operation. Suitable lifting eye, lifting lug, rail, extension rail, skid pulling lug, ceiling hook, stair, platform, hinge frame, etc. shall be provided as required. Safety means shall be also provided.

9.4 The equipment shall have markings, such as the centerline mark, match-mark, etc, in order to facilitate the installation works at the Site.

9.5 In the design of the equipment, a seismic force of 0.10 times the weight in any direction shall be included, where necessary.

9.6 All surfaces of water passages shall be of even and smooth finish to prevent turbulence, and provided with a smooth-contoured hydraulic surface. The runner, guide vanes and discharge ring shall be finished to a smooth surface and shall be free from hollows, depressions, projections or other surface imperfections that may cause local cavitation. The surface finish on these components shall not exceed the following maximum surface roughness in accordance with ANSI B46.1, "Surface Texture".

<u>Surface</u>	<u>μm</u>
Runner blades negative pressure side	1.6
Other part	3.2
Runner except runner blade	3.2
Discharge ring	6.3
Guide vanes	12.5
Contact surfaces of adjacent guide vanes	1.6

9.7 All slings, beams, bracing, etc., necessary for handling, assembling and placing of the equipment shall be supplied by the Contractor.

9.8 Where lifting equipment is otherwise itemized, this shall be considered a minimum requirement. All special slings, beams, bracing, etc, supplied by the Contractor shall become the property of EGAT.

TG-10 ELECTRICAL EQUIPMENT

10.1 The Contractor shall supply all single-line and three-line diagrams, conceptual design description document, block diagrams, logic diagrams, schematic control diagrams, Trip matrix diagram, cable and wiring diagrams, inter-connection diagram, equipment and signal list with their location, material take off, equipment arrangement, detail drawings, and any other documents as deemed necessary to complete the works.

10.2 The Contractor shall coordinate all equipment selected and supplied by it, ensuring its compatibility and adequacy for the purposes specified.

10.3 The Contractor shall supply all special test equipment and instruments required and supervise the testing of the equipment.

10.4 The equipment furnished shall be complete, including all safety devices and controls appropriate to the service intended and required for safe and reliable operation. Components and parts regularly replaced during scheduled maintenance periods shall be readily available in Thailand.

10.5 All joint of bus, male-female for plug-in and draw-out contact shall be silver-coated not less than 0.0127 mm. thickness.

(a) Motors

All motors shall be in accordance with NEMA or IEC, suitable for continuous operation and direct on-line starting.

All motors shall be totally enclosed, weatherproof, fan-cooled type suitable for operation in high ambient temperatures and high humidity conditions. Motors up to and including 370 W shall be 230 V, single-phase. All motors above 370 W shall be 400 V, three-phase. The starting current at full voltage shall not exceed six times full load current at normal starting torque.

All motors shall be capable of continuous operation at rated output, at any frequency between 47 Hz and 53 Hz at nominal voltage, and plus or minus 10% of nominal voltage at nominal frequency, without injurious overheating. The induction motors shall not be affected by a transient rise of 40% in frequency due to load rejection of the unit(s).

Motors larger than 370 W shall be supplied from separate circuits, which are provided with over-current protection.

The motors and motor lead insulation shall have Class F, insulation and a continuous rating at ambient temperature.

Wound rotor motors will be acceptable only if a squirrel-cage type is not satisfactory for the duty.

All motors shall be horizontal shaft unless an integral part of the equipment. Ball or roller bearings shall be used, and vertical motors shall have approved thrust bearings. Ball or roller locating cages shall not be in contact with the races. Lubricating devices shall be provided for all bearings. Where ball and roller bearing housings are fitted with grease nipples they shall incorporate an approved grease escape valve.

The motor terminal boxes shall be weather and vermin-proof and fixed to the motor frame. The terminal studs shall be sized for the current duty required and marked in accordance with NEMA ICS4 where applicable. All terminal boxes shall have cable adapter plates, sealing chambers or conduit entries.

Arrangement of the terminal box shall facilitate installation of cables, allowing interchanging of any two-phase leads, without disturbing the sealing compound, if used at cable terminations.

(b) Magnetic Contactors and Motor Starters

Magnetic motor starters shall have the following features and/or accessories:

- molded case circuit breaker disconnect with thermal time delay and instantaneous trips
- a 230-V ac operating coil
- motors rated under 10 kW shall have thermal overload protection in each phase, temperature compensated with thermal elements and phase failure detection correctly related to motor nameplate, current and type of enclosure.
- Motors rated 10 kW and above shall have embedded thermistors for protection, and protection devices
- auxiliary contacts for the control of related auxiliary devices such as motor heating, indicating lights, interlocks, etc.

All starters and contactors shall comply with IEC Publication 60947-4-1 type II and shall be suitable for direct on-line starting of motors and continuous electrical duty capable of 30 operations per hour appropriate to the duty required with manual resetting and under voltage release features.

All motors shall be provided with quick-break molded case circuit breakers, as described in Section (d), with operating handle lockable in OFF position. They shall be rated to interrupt the full-load current of motor or other equipment in the circuit.

Magnetic contactors shall be made of arc-resistant metal and have sufficient capacity against current inrush. The contacts shall be designed to obtain high contact pressure and positive seating. Both moving and fixed contact shall be designed for easy assembly-disassembly without removing any wiring or dismantle the contactor.

Contactors and motor starters of the latched type shall use mechanical latching and shall comply with the following requirements:

- latching mechanisms shall be positive in operation under all conditions of service with an operating coil voltage range of 80% to 110% and trip coil voltage range from 50% to 110%
- when the coils are energized at rated voltage for 30 seconds, the specified temperature rise limits shall not be exceeded.

Contactors and motor starters of the electro-magnetic held type, shall comply with the following requirements:

- the contactors shall close completely at any voltage where pick-up occurs
- with 70% voltage at the coil terminals the main contacts shall not chatter nor part when the stator current resulting from a stalled motor is being conducted.

(c) Relays and Devices

Relays shall comply with IEEE Std. C 37.90 and shall be provided with non-flammable dust and moisture proof cases.

Relays shall be of the plug-in or withdrawable type and the plug-in connections shall be made and broken by pressure contacts.

Relay contacts shall be adequately rated for the service conditions. The coils shall be continuously rated and shall have a tropicalized finish and be air-sealed to prevent corrosion by hydrogen sulfide gas.

Electric contacts of relays, timers, dial type thermometers, thermal relays, oil level relays, oil pressure relays, air pressure relays, limit switches, etc, shall be able to safely break a current of possible maximum inductive load (2 A) and 48 V dc. All electric contacts shall be anti-fungi protected.

A.C. operated coils shall be suitable for operation at 230 V ac +10% to -15%. D.C. operated coils of control and trip relays shall be suitable for operation at 48 V dc in the range of 80% to 120% of nominal voltage for control relays and 50% to 110% for trip relays.

Trip relay, dual coils solenoids and latch relay shall not be continuously energized, limit switches or self contacts shall be designed to cut-off the coils after being energized and latched.

Timing delays shall adjust easily and the relays shall hold that adjustment. The timing range of the relays shall overlap the expected setting plus or minus 50% unless the timing range is included with the specification. The setting adjustment shall be calibrated clearly.

A minimum of one spare normally open contact and one spare normally closed contact shall be provided on each relay in addition to the contacts required by the control scheme.

Relays shall be direct acting and interposing relays kept to a minimum consistent with consideration of the number of contacts required.

Mechanical targets (operated at 48 V dc) shall be individually provided with any equipment that is annunciated as a group due to a faulty condition. In this manner the faulty equipment can be easily identified.

Selector switch, control switch shall be of heavy-duty design, the body shall be made of high mechanical strength insulation.

(d) Molded Case Circuit Breakers

All single-pole, two-pole and three-pole molded case circuit breakers shall have thermal time delay and instantaneous trips with ON-TRIP-OFF indicating operating mechanisms. Circuit breakers used in conjunction with motor starters or contactors shall have the operating mechanisms interlocked with the starter or contractor cover, so that the cover cannot be opened unless the circuit breaker is open. The circuit breakers shall comply with the applicable sections of IEC Publication 60947-2. Circuit breakers shall be bolt-in type, interchangeable, temperature compensated, quick-make, quick-break type, with symmetrical fault level interruption designed by calculation.

A group alarm contact shall annunciate an open breaker and each breaker shall have an individual light or mechanical indicator, which shall come on when the breaker is opened or tripped.

(e) Fuses

Fuse links and holders shall be dead front type. The rating of each fuse link shall be appropriate to the service conditions and shall provide discrimination with other fuse links or current protective devices connected in series.

(f) Pilot Devices

Pilot devices such as selector switches, push-button stations, thermostats, etc, shall be of the heavy duty, oil-tight type, housed in a dust-tight enclosure designed especially for the type of environment. Local stop buttons near the motors shall be lockable in pressed position for maintenance.

(g) Indicating Lights

All indicating lights shall be of fluorescent or LED type for long life and service under conditions of shock, vibration and rough handling unless otherwise specified.

The functions associated with the colors of the indicating lights shall be as follows:

- (i) red for "in service" conditions
- (ii) green for "out of service" conditions

(h) Instruments and Meters

All instruments and meters shall be heavy-duty industrial type, dust-proof and capable of withstanding severe shock or vibration. The instruments shall comply with ANSI C39.1/ IEC 60051.

All instruments flush mounted on the outside of enclosures shall be square case, have non-reflective glass and be provided with uniform high-grade narrow bezels.

All instruments shall have circular scales with a total pointer deflection of not less than 240 degrees. Normal working indication shall correspond from 50 to 75% of full-scale deflection.

The scales for ammeters in motor circuits shall be compressed so 20% of full-scale deflection (F.S.D) occurs at 40% full-load current (F.L.C) and 90% of F.S.D. at 120% F.L.C. The scale shall be linear in the range from 40% to 120% and compressed above 90% F.S.D. to indicate six times F.L.C. at 100% F.S.D.

The instruments shall be damped to ensure that the pointers come to rest rapidly after being deflected from their previous positions. End stops shall be provided to prevent damage to movements, pointers and suspensions under transient conditions.

Devices used for routine checking, zero adjustment and re-calibration shall be easily accessible from the front of the enclosures.

Electrical thermometers shall have detector resistance elements (embedded temperature detectors) of platinum wire with 100 Ohm resistance at 0 °C.

Instrument scales shall be linear unless otherwise specified and shall be calibrated in their units of measurement. Pressure gages shall be calibrated in Newton per square meters or Pascal and kg/cm² for the convenience of the operators.

Rated red marked shall be marked on the scale of instrument.

Bourdon tube for instrument shall be of built-in spiral stainless steel armor with outer plastic jacket.

(i) Convenience Outlets

Convenience outlets in the control cabinets shall be rated for 15 A, 250 V double 3-pins plug pattern determined by Thailand local codes and regulations or Universal socket with minimum type A B C O with ground as approved by the Engineer.

Where necessary, outlets shall be in weatherproof enclosures or suitably protected from weather.

(j) Light Switches

Light switches and door operated switches in the control cabinets shall be rated for 15 A at 250 V, suitable by Thailand local codes and regulations and as approved by the Engineer.

Where necessary, switches shall be in weatherproof enclosures or suitably protected from weather.

(k) Pressure, Level and Flow Switches

The sensing switches shall have weatherproof enclosures and shall be mounted for easy adjustment and for rigidly locking in position after being adjusted. They shall be of

heavy-duty rating and shall have stainless steel rotating parts and permanently lubricated bearings. SPDT contact. Pressure, temperature, level, flow etc, type switches shall have suitable voltage and current ratings.

(I) Equipment Enclosures

All outdoor electrical equipment enclosures shall meet the IEC Publication 60529 Index of Protection Rating IP55. All indoor electrical equipment enclosures shall meet the IEC Publication 60529 Index of Protection Rating IP41 and IP23 for generator panel.

All hinged doors shall be equipped with semi-concealed hinges and handles with cylinder type locks. The locks on each set of doors shall be such that the key for operating one set of locks cannot operate any other set of door locks. If a lock for each door is not feasible, the Contractor may furnish a single-cylinder type lock for each set of doors, complete with the necessary mechanical interlocks.

All compartment doors shall be so constructed that they will not seize in the event of a fire within the cubicle.

Removable panels shall be provided, where required, to permit convenient access to all internal equipment and connections to the incoming bus ducts. The removable panels shall be supplied with suitable fastening devices, and shall be of a size that can be conveniently handled by one person.

Entrance bushings shall be used for insulating and supporting the buses and bus connections that pass from one compartment into another.

All materials used in the cubicles, such as bus insulation, bus supports, etc, shall not independently support combustion.

Safety transparency insulation shall be provided to prevent accidental contact with live part as required.

The cubicle required ventilation shall consist of ventilation vents or louvers with filter. The filter shall be of a type easily replaceable and readily available in Thailand. All ventilation opening shall be provided with corrosion-resistant screen to keep out rodents and insects, dust filter mean shall also be provided. Temperature rise in any electronic cubicle shall not more than 15°C.

Medium voltage cubicles which are required to observe the operation of the equipment such as generator disconnecting switch, dynamic brake switch etc. shall be furnished with safety glass inspection window with lighting on-off switch locate near the window.

All medium voltage cubicles shall be furnished mimic bus with identification label showing main equipment inside the cubicle such as CT, PT, LA, SA, breaker, DS, grounding DS etc. status of the equipment indicating lamp shall also be provided.

Equipment and connections within each compartment shall have their mounting bolts arranged so that it will be possible to replace them without removing from service equipment in adjacent compartments.

Anti-condensation heaters shall be fitted in all enclosures or panels containing control or relay equipment, and in all enclosures and mechanism boxes located outdoors. Each panel heater shall be completed with a circuit breaker as described herein and an adjustable thermostatically controlled heater unit suitable for 230 V ac, 50 Hz operation. The heater capacity shall be sufficient to raise the internal ambient temperature 5°C and not exceed the maximum permitted rise in temperature for the equipment.

Panel lighting and a convenience outlet shall be fitted in all enclosures. Each panel shall be completed, with a circuit breaker as described herein, a fluorescent or LED light with a removable wire guard, door activated switch and a convenience outlet. The equipment shall be suitable for 230 V ac, 50 Hz operation.

Removable aluminum or stainless steel gland plates shall be supplied and located with adequate working clearance for the termination of cables. Under no circumstances shall the floor or roof plate be used as a gland plate. The cables and wiring shall enter from the bottom or top as approved or directed by the Engineer.

Anti-vibration facilities such as dumping pads at the foundation base shall be provided if the excessive vibration is expected. In the design of anti-vibration, an attention shall be paid not to cause any excessive sway of the cubicle amplified with the resonance between the cubicle's natural frequency and that of vibration source.

(m) Equipment Wiring and Accessories

All internal equipment control wiring shall be 600 V, stranded annealed copper conductor 70°C PVC insulation in accordance with IEC Standard or approved equal.

Minimum wire size shall be as follows:

1. Low-voltage power cable	2.5 mm ²
2. Control circuit	1.5 mm ²
3. Instrument circuit	1.0 mm ²
4. Current transformer circuit (CT)	4.0 mm ²
5. Potential transformer circuit (PT)	2.5 mm ²
6. Switchboard and panel cables	1.5 mm ²
7. Lighting Circuit	2.5 mm ²
Note: The above list of minimum cable sizes is not applicable to small current circuit such as testing, measuring instrument and internal wiring of power distribution boards.	

Power cable shall be determined by rating of protection device which the cable shall be greater than, minimum wire size shall be 2.5 mm²

Rated voltage

Low voltage Power cable (AC/DC power cable):	600/1000V
Control and instrument cable (except power cable):	600 V
Lighting cable:	450/740V

Cable for other special circuits shall be as recommended by manufacturer with approval by EGAT. Insulation wiring color code shall conform with the new IEC for

- AC (brown, black, grey, sky blue)
- DC (+ brown, - grey)

Maximum Allowable voltage drops

Feeder	Voltage drop
AC/DC power feeders	2%
Motor cable at full load	3%
Motor cables during starting	15%
Lighting circuit, i.e. from 400 V distribution board to furthest lighting fixtures	3%
UPS circuit, i.e. from UPS to instrument	3%
Battery circuits	1%

Careful consideration shall be made to prevent capacitance effects on long runs of control wiring from affecting the performance of the control circuits. In locations where cables are susceptible to corrosion due to atmosphere or soil pollution, special cable sheathing and additional protection shall be provided.

Internal wiring of solid state equipment may use solid conductors having a minimum size of 0.5 mm².

All current and potential circuits from protection relays and indicators, and trip circuits from protection relays to lockout relays shall be 7-strand copper conductor or 19-strand copper conductor, for connections with high flexibility requirements.

All wiring connections shall be readily accessible and removable for test or other purposes. Wiring between terminals of the various devices shall be point-to-point, splices or tee connections are not acceptable.

Circuits of different voltages or voltage class shall not be run in the same wiring trough. Separate wiring troughs or ones with barriers shall be used for this purpose. All secondary wiring shall be kept separately from primary connections.

Circuits of similar nature shall be grouped together on terminal blocks.

The following color identification shall be applied to the insulation of wires used for internal wiring of control cabinets, control boards, cubicles, control boxes and auxiliary equipment.

- Secondary circuit of potential transformer red
- Secondary circuit of current transformer black
- dc circuit blue
- ac circuit except power circuit yellow

- | | |
|-----------|------------|
| - neutral | white grey |
| - ground | green |

Equipment wiring may be arranged and constructed on a comprehensive modular system. The Contractor shall submit details of the modular wiring system for the approval by the Engineer. Equipment for which a modular wiring system is not available or not approved the following requirements shall apply.

- All wiring shall be carried out in accordance with wiring diagrams. Wiring diagrams shall be drawn as seen from the wiring side and shall show all terminals of selector switched, relays, contactors, terminal blocks, etc, in their correct relative positions.
- Wiring shall be neat and securely bundled, cleated, enclosed in ducts or conduits, or supported on trays and run in the most efficient manner from point to point. Wiring shall be kept bundled with strips of plastic ribbon material at suitable intervals. Lacing of wire bundles will not be accepted. Wherever wiring is cleated to metalwork, it shall be insulated from the metal surface and shall be cleated by means of insulated straps in an approved manner. All wiring shall be left sufficiently long and neatly looped to allow a fresh termination to be made should the original termination break off. Where wiring crosses between a fixed panel and a hinged panel it shall be arranged so that flexing is reduced to a minimum and strain is not transmitted to any terminal.
- The ends of each wire shall be provided with an approved type of crimped wire termination equal to the UTILUX supergrip or A-MP pre-insulated type. The copper sleeve shall be insulation, applied with a ratchet type tool which leaves an identifying mark on the crimp thereby enabling post crimping checks on the tools used. The number of wires per terminal shall not exceed two.

The wire numbers used on the Contractor's diagram and equipment, shall be those allocated on overall circuit diagrams by the Contractor who produces the relevant circuit diagrams.

Wire marker ferrules shall be of heat imprinted white tube with black character shall be fitted to each end of each wire to give the wire number as shown on the wiring diagrams. Wire markers shall be read from left to right.

(n) Terminal Blocks and Terminals

Terminal blocks for all external wiring shall be stud type and shall be suitable for ring tongue insulated pressure compression type connectors. Terminal blocks for current and voltage transformer circuits shall be stud type with a shorting bar provided for incoming CT secondary circuits. Terminal blocks for internal wiring shall be of the 600-V molded block type with an insulating barrier between terminals. Terminals of electrical devices shall comply with the following requirements.

Terminals shall be either:

- studs or bolts and nuts, of not less than 5 mm, or
- approved screw clamp type terminal of a type in which the clamping screw does not directly contact the conductor

- for wires not larger than 1.5 mm², cheese head screws not less than 3 mm.

Terminal material shall be copper, copper alloy, stainless steel or zinc plated and passivated steel.

Terminals shall be rigidly fixed in position.

Terminals of devices shall be suitable for 2200 V ac test.

Terminals for circuits with voltage 100 V ac and above or 48 V dc and above shall be segregated and fully shrouded to prevent accidental contact with live parts.

Each stud or screw type terminal shall have the wire termination fastening secured by a spring locking washer or second nut.

Terminals of devices shall be identified by a character(s) on the exposed terminal base and this character(s) shall be used in the wiring and circuit diagrams.

The terminals of motors or other equipment shall have pressure compression type terminal lugs.

Each terminal block shall have marking strips and shall be equipped with crimp style terminals for 2.5 mm² or more. Terminal blocks shall be provided with at least 25% but not less than 5 pieces, surplus terminals as spares for each control board and cabinet. No more than two wires shall be connected to one terminal.

Running number of terminal block shall be run from top to bottom and left to right hand side.

Terminal blocks shall be located in such a way that the incoming cables shall terminate neatly and conveniently. All numbered terminals on the schematic diagrams shall be brought out to the terminal block and labeled accordingly. All terminal blocks shall be anti-fungi protected.

(o) Electronic Equipment

All cabling to the electronic equipment shall terminate on U-links equipped with test sockets. Testing the input condition shall be permitted with the U-links in position. Where possible, visible indication of the input conditions shall be displayed on LED's in series with the input circuit.

Inputs to electronic equipment derived from sources in close proximity to equipment operating at voltages higher than the breakdown voltage of the electronic equipment shall be isolated.

Outputs from electronic equipment routed in close proximity to equipment operating at voltages higher than the breakdown voltage of the equipment shall be isolated.

Printed circuit cards shall be of quality fiberglass material. The cards shall be flow soldered and covered with protective enamel, adequate to protect the card from hydrogen sulfide gas encountered on site. Components and test points shall be clearly labeled. Type number, serial number and a reference to the relevant drawing number shall be

clearly labeled on the PC card. Labeling shall be permanent and shall withstand cleaning with Freon or similar solvent.

Testing facilities shall be provided such as extension card, testing pin on cards, testing cards, etc.

Printed circuit cards shall be provided with frames and mounted in racks. Clear access shall be provided to the cards and their connectors. Auxiliary equipment mounted on the rear of the card frames shall be mounted on a hinged plate to facilitate the access to the card frames and wiring.

Mechanical devices shall be provided, these devices shall be designed to secure the printed circuit cards in the socket, and also to be used for plug and unplug the printed circuit cards to and from the socket.

A stranded cable shall be provided where movement occurs between the plug or socket, relative to the cable.

Joints internal to cubicle wiring and between cubicles are not permitted

Withdrawable cards, modules and cable plugs shall be keyed, coded or otherwise marked to ensure there is no possibility of incorrect replacement.

PC boards equipped with modular edge connectors are preferred over PC boards using an extension of the circuit track as a male plug.

Contacts on both printed circuit cards and female sockets shall be gold plated.

Components shall not be used as through-connectors. If through-hole plating is not employed, separate through-connectors shall be provided by track connecting pins.

The following information shall be supplied for each component used:

- name of manufacturer/distributor
- name of second source manufacturer/distributor
- data sheet giving the complete specification for the component.

All components shall be of proven reliability and shall be conservatively rated. The availability criteria for a completely designed and assembled operating system shall be not less than 99.8%.

The surface temperature of any component shall not exceed 70°C at an ambient temperature of 40°C. The equipment shall be designed to operate under the following service condition:

- temperature range 0°C to 50°C
- relative humidity 95% at 38°C, non condensing
- dust 10 mg/m³

All equipment shall withstand test voltages as follows:

- relays, switches, PT/CT circuits,
I/O boards, dc & ac control
and power circuits 1500 V ac, one (1) minute
- electronic equipment 500 V ac, one (1) minute

The equipment shall be protected for surges and shall include surge protection components, suppressors, noise filters, and electromagnetic shields. All input and output of the equipment, including the communication line, power supply unit, transducer, etc. Radio interference suppression shall be to standard EN 55022 and EN 55014, interference immunity shall be to IEC 61000 Electromagnetic Compatibility, EN 60801 and VDE 0843.

The assembled equipment and components shall withstand shock and mechanical vibrations without a failure or mal function of the equipment. The equipment shall be tested for mechanical performance to international standards.

All components shall be of standard ranges and shall be available from more than one source. Semiconductors shall be to industrial or US Military specifications.

Where microprocessors or similar programmable or preprogrammed circuits are utilized, the programming practice with performing editor shall conform to IEC 61131-3 Programmable Controller – Part 3 Programming Language, any document, hardware and software shall be of English version. The operating system shall be of Window NT™ or UNIX™ with x-windows or VMS™ with x-windows. The system shall be an open hardware and software platform, market wide type hardware shall be compatible of all software that submitted in this Contract. The Contractor shall supply the following:

- function block diagram
- ladder diagram
- instruction list
- control system description
- sequence function chart
- program listings
- software program
- logic diagram
- I/O listing and I/O connection diagram
- loop diagram/Signal Flow diagram
- flow chart

- software license
- necessary document/software
- facilities for maintenance, reprogramming, on-line and off-line monitoring, modification, upload, download, diagnosis, trouble shooting, testing, etc., both hardware and software shall be provided
- copies of all information required to purchase and program the system or to replace components. A control panel allowing testing of all functions performed (with facilities to run, single step, display register, display memory, change program counter, etc).

(p) Motor Control Centers (MCC)

Motor Control Centers (MCC) shall comply with IEC standards.

Local box shall be provided as required. Local box shall be furnished with RED, GREEN and AMBER indicating lamp for START, STOP and FAULT respectively, START and STOP push button, etc. The STOP push button shall be of maintained, manual reset type.

(q) Equipment Mounting and Supports

The support structures shall be fabricated from welded structural steel members. All structural steel, bolts, nuts and washers shall be hot-dipped galvanized with a finish coat of zinc chromate.

The equipment and its supporting structures shall be so designed to prevent any distortion under a suddenly applied load, which would adversely affect the operation of the equipment.

The structural design shall be subject to the Engineer's acceptance

All support structures shall have provision for cleats or supports with clamps for attaching the grounding cables (not less than 95 mm²) to the structure. These supports shall be welded to the structure prior to galvanizing.

All wall-mounted equipment shall be fastened to a galvanized channel support structures.

(r) Equipment Grounding

All equipment enclosures containing control or power devices up to 230 V shall have an external ground connector. Hinge door or swing panel shall also be grounded by flexible wiring.

All equipment enclosures containing multiple control units or power devices 400 V and above shall have an earth copper ground bus extending the width of the equipment. The current density of copper ground bus shall not exceed 200 A/mm² under the specified earth fault conditions, however, its cross-section area shall not less than 50 mm². Two ground connectors suitable for powerhouse stranded copper ground cables, but not less than 95 mm², shall be provided at opposite ends of the ground bus.

(s) Interposing Relay Panel

Interposing relay panel shall be provided (if required) for interconnection of signal cables between electrical switchgears and instrument panels.

The relay panel shall be rated as follows:

- Circuit System DC, 2-wire
- Voltage 48 V DC

The power supply of this panel shall be provided from the DC distribution Board.

Interface signals between electrical equipment and instrumentation such as motor start and stop, air-operated valves open and close, etc, may be via interposing relays. These interface signals shall include, but not be limited to, the following:

- Interface signals as shown in piping and instrument diagram
- Interface signals as shown in instrument interlock diagram
- Necessary interface signals in accordance with electrical design.

Relays shall be grouped, taking into consideration the process section.

Relays shall have a minimum of two contacts, and timers shall be provided where required.

At least 20% spare relay and contact circuits shall be provided in the interposing relay panel for future use.

The interposing relays panel shall be a vertical self-standing, sheet-metal enclosed assembly with bottom sheet plate. The enclosure shall be so constructed as to allow back access to the inside for inspection, maintenance and connection of external wiring.

Relays shall be socket mount type which can be removed without disconnecting the wiring and have positive means of retaining them securely in the service position.

Relay socket bases shall be mounted on racks or frames which shall be mounted in the panel in such a way as to provide easy access.

The panel shall be provided with a grounding terminal on the outside of the enclosure.

Terminal boards suitable for connection of external wiring cables to conductors of internal wiring cables shall be provided in the enclosure.

Terminal boards shall be solderless type and provided with crimp terminals.

Terminal boards shall have terminal marks for convenience of cable connection work. All metallic surfaces of the panel shall electrolytically painted. Should there be any contradictions between the manufacturer's recommendations and the above, then the most stringent should apply.

The following accessories shall be provided with panel:

- Crimp terminals
- Bolts, nuts and washers
- Other standard accessories

TG-11 PIPING

All piping larger than 65 mm diameter shall be formed in the manufacturer's shop. A flange shall be fitted to one end of pipe in the manufacturer's shop, and another flange shall be fitted to the other end of pipe in the field connection. Flanges attached to pressure pipes shall be welded from both inside and outside.

Rim joint for the connection of copper tube (not more than 20 mm in diameter) shall be applied at the site.

Connection of pipes mounted on the equipment shall be supported so as not to convey the weight of pipes to the equipment. The Contractor shall design the position of all pipe fittings to permit maintenance work with minimum pipe disconnection.

The Contractor shall furnish drain cocks and air exhaust valves, etc., at necessary positions in the piping system.

Piping shall be sized for the maximum anticipated flow with velocities in the range of 1 to 3 m/s. Pipe longer than 10 m shall be not less than 25 mm nominal size to ensure ruggedness or shall be adequately supported.

Line friction shall be calculated using conservative friction factors, equivalent to a Hazen-Williams coefficient of $C = 100$ for steel pipe.

Due allowance shall be made for water hammer in accordance with AWWA C-101.

TG-12 WELDING

12.1 All welding procedures for pressure vessels or pressure containing parts shall conform to the requirements of ASME Sections VIII, Division 1 and ASME Sections IX. Welding procedures for all other components, except pressure vessels, shall adhere to the accepted welding standards of the American Welding Society (AWS) or relevant ASME code.

12.2 All filler metals used in electric arc welding process shall conform to the specifications outlined in ASME Sections II, Part C - Specifications for Welding Rods, Electrodes, and Filler Metals or an equivalent standard approved by the EGAT Inspector.

12.3 The contractor shall provide relevant Welding Procedure Specification (WPS) and Procedure Qualification Record (PQR) covering all site and factory welds. These procedures shall comply with ASME Sections IX and shall be submitted for approval before any site welding activities commence.

12.4 Contractor shall submit joint design drawing for any non-standard welding joint in critical components.

12.5 For typical joint misalignment, the contractor shall follow the requirements of ASME Sections VIII, Division 1 or an equivalent standard approved by the EGAT Inspector.

12.6 Welders shall have prior experience in ASME-certified projects or companies or shall have previously qualified through a test certified under ASME or ISO standards. Before commencing welding activities on-site, all welders shall undergo a site welding qualification test. Test specimens shall be inspected using visual examination (VT) or liquid penetrant examination (PT), with results subject to approval by the EGAT Inspector. The contractor shall supply all necessary test specimens and equipment. The EGAT Inspector reserves the right to request requalification tests for welders at any time.

12.7 All non-destructive testing (NDT) procedures shall comply with the requirements of ASME Sections V - Nondestructive Examination. Acceptance criteria for all NDT methods shall be in accordance with ASME Sections VIII, Division 1 or an equivalent standard approved by the EGAT Inspector.

12.8 After welding, all welded joints shall be cleaned to remove slag, spatter, oxidation, and other contaminants. Cleaning shall be performed using appropriate methods such as grinding, wire brushing, or chemical cleaning, in accordance with the ASME or AWS standards. The cleaned surfaces shall be inspected and approved by the EGAT Inspector before proceeding to the next stage.

12.9 If applicable, painted surfaces shall be prepared and coated in accordance with TG-14 Painting. The contractor shall ensure that all surfaces are properly cleaned and free from oil, moisture, and contaminants before applying any primer or paint.

TG-13 NAMEPLATE AND MARKING

13.1 Nameplates, instruction plates, labels and tags, warning plate, warning signs, identification label and any marking whatsoever on the equipment and parts and accessories thereof shall be in English language, big enough for easy reading, except where otherwise indicated in the specifications.

13.2 Nameplates shall be made of stainless steel plate, except nameplates attached to indoor control cabinets, control boards, cubicles and control boxes which may be made of engraved laminated acrylic resin, screw driven, and shall be in English language (white letters on black ground).

13.3 All equipment shall be identified, and all nameplates wording shall be subject to the Engineer's approval.

13.4 Nameplates shall contain, but shall not be limited to:

- Name and address of manufacturer
- Type and designation or serial number
- Phase identification label
- Rated maximum voltage
- Rated maximum current

- Rated frequency
- Nameplates for control devices
- Accuracy levels, current and voltage ratings of instrument transformers
- Nameplates identifying ratings of all protective devices
- Date of manufacture.

13.5 Phase and polarity identification means shall be furnished as follows;

- Colored insulation cap for power, CT, PT cable and wirings
- Colored insulation of bus

For AC 3 phase

Phase A	-	Brown
Phase B	-	Black
Phase C	-	Grey
Neutral	-	Sky Blue
Ground	-	Green/Yellow
Ground/Earth	-	Green/Yellow

AC Single phase

Line	-	Brown
Neutral	-	Sky Blue

DC

Positive	-	Brown
Negative	-	Gray

Medium and High Voltage Equipment label

- A - Red background White letter
 - B - Yellow background Black letter
 - C - Blue background White letter
- Size of letter shall not be smaller than 20 x 15 cm. (wide x high).

TG-14 PAINTING

The Contractor shall apply prime, intermediate and finished coating as specified hereafter to all exposed parts of all equipment, fabrications, structures, vessels, electrical and control panel in the factory.

Areas which would be difficult or impossible to be painted after the construction is completed shall be painted at a stage during the construction when painting is possible.

All stainless steel, galvanized, bronze and aluminum surfaces, anchor bolt threads, machined, mating and close clearance surfaces shall be left unpainted and shall receive a corrosion-preventive temporary protective coating to provide protection during transportation to and storage at the Site.

Except miscellaneous metalwork specified, all surfaces which are embedded in concrete, surfaces and edges to be field welded, and other surfaces for which painting is not specified in the final installed mode, shall be prepared to SSPC-SP1 and SP2 or SP3. The areas shall receive one shop coat of an approved primer.

The protective coatings at field welds shall be removed prior to welding except surfaces to be painted with weldable coating. Final shop painting shall not be applied within 100mm of field welding.

All dirt, dust, sand, grit, mud, oil, grease, rust, loose mill scale, and other objectionable substances shall be removed from surfaces to be painted before applying paint. Surface preparation shall be performed in a manner which will prevent dust and other airborne particles from contaminating freshly painted surfaces. All oil or grease shall be removed from surfaces with solvent before starting mechanical cleaning.

Paint shall be applied in accordance with SSPC Paint Application Specification No. 1 "Shop, Field, and Maintenance Painting" and as specified herein. Paint shall be applied only when temperature of surfaces to be painted is above the minimum surface temperature recommended by the paint manufacturer. Paint shall not be applied under any of the following conditions:

- When the temperature of the surface to be coated is above 40 °C.
- When insects or windblown dust, dirt, or debris would adhere to the freshly applied paint.
- When atmospheric conditions are causing condensation on the surface.
- When temperature of surface to be painted is less than 3 °C above the dew point.

The paint shall be applied using air or airless spray techniques. When painting on any surface has commenced, the painting operation shall be completed as soon as practicable, without delays. The drying time between coats shall not be less than 12 hours.

Paint shall be roller or brush applied, as required by EGAT, in areas where spraying may present hazardous conditions to personnel or equipment.

The Contractor shall provide EGAT with a list of paint manufacturers and equipment's coating system for approval.

Finish paint colors will be in line with EGAT's standard specification or decided by EGAT.

After installation of material and equipment is complete, all painted surfaces shall be touched up before application of final field coat.

The Contractor shall supply matching touch-up paint for future use by EGAT. The quantity supplied shall be at least 12 liters of each color and type of coating used to do the original shop painting and final field coat.

Final thickness of protective coatings shall be checked by an approved film thickness gauge, supplied by the Contractor, calibrated on metal identical in composition, thickness, surface preparation and finish to that being painted. Dry film thickness (DFT) shall be performed in accordance with SSPC-PA2 "Measurement of Dry Coating Thickness with Magnetic Gages".

When called for in the specifications, painted surfaces shall be subject to electrical inspection by a holiday detector, furnished by the Contractor.

Where imperfections, discontinuities or holes in the finished coating are found, the inadequate coating shall be prepared in a manner acceptable to the Engineer, then over-coated with one additional finish coat. Thickness of this coat shall be the minimum recommended by the paint manufacturer and in any case not less than 100 μm . The Engineer shall determine the extent of over-coating needed.

Protective coatings shall be guaranteed with respect to materials and workmanship. The guarantee shall cover, without limitation, separation between the steel and the protective coatings.

The surfaces to be painted in the shop or at site, as applicable, shall include, but not necessarily be limited to

- stay ring, stay column, discharge ring, operating ring, servomotors, draft tube liner, turbine pit liner, walkways and platforms.
- generator and exciter
- all sumps, pressure tanks and bearing shells (interior and exterior)
- governor, valves, prefabricated piping, servomotor cylinders
- interconnecting exposed carbon steel piping shop fabricated in sections
- electrical switchgear, cubicles and control panels
- all other equipment and accessories associated with the above.

14.1 Underground Piping Protective Coatings

The protective coating for the steel pipe, special sections, connections, and fittings to be placed underground and manhole sections shall be tape coating system. The system shall consist of tape wrapping primer, inner-layer, outer-layer and mastic filler. The minimum overlap shall not be less than 50 percent of tape width. Prior to applying the inner-layer tape, each longitudinal weld seam shall be primed and the covered with a 4 inch strip tape having the same properties as the inner-layer tape. The coating system for the steel pipe shall conform to AWWA C 214 "Tape Coating Systems for the Exterior of Steel Water Pipes" and AWWA C 209 "Cold Applied Tape Coating for the Exterior of Special Sections, Connections, and Fittings for Steel Water Pipelines".

The protective coatings shall be shop applied after fabrication and before erection except for the surfaces at the pipe ends. The coating shall be left off of pipe ends for a distance of approximately 150 mm to permit the welding of joints without injury to the coatings.

After the sections of pipe are welded together, the areas left uncoated and all damaged areas shall be cleaned and coated.

The tape coating material shall be cold-applied tape consisting of PE or PVC backing and adhesive sealant. The tape coating material for the steel pipe shall be constructed of 0.5 mm thickness (before wrapping) for the inner-layer tape and 0.75 mm thickness (before wrapping) for the outer-layer tape. The tape coating material shall be conformed to AWWA C 214.

The tape coating material for special sections, connections, fitting shall be constructed of 0.75 mm. thicknesses (before wrapping) for the inner-layer and outer-layer tape coating. The tape coating material shall be conformed to AWWA C 209.

The Contractor shall supply mastic filler material for filling the reinforcing plate contours. The mastic filler shall have specific gravity 0.8-0.9 and meet the requirement of AWWA C 217 and the same manufacturer with tape.

14.2 Paint Colors and Paint System

Except as otherwise directed by EGAT, the finish color of equipment shall be in accordance with the following requirements.

- The finish color for all indoor equipment and cubicles, both inner and outer surfaces shall be RAL no. 1014 (Ivory).
- The finish color for all outdoor equipment and cubicles, both inner and outer surfaces shall be RAL no. 7036 (Platinum Gray).
- The finish color for fire alarm, fire protection and fire fighting system shall be RAL 3000 (Flame Red).

Except for the structural steel of buildings and the civil miscellaneous metal work which the paint system shall be accordance with Clause SC1 and SC3 specified CW-TS chapter 20 Painting and Coating, the paint system shall be in accordance with the following list.

In the event of deviation between these paint systems and any painting provision specified in other sections, the superior paint system decided by EGAT, the Engineer shall govern.

Material/Equipment	Coating System (CS)
1. Structural Steel for Powerhouse and other buildings Including non-embedded exterior surface of penstock	CS-M1
2. Surfaces in Contact with Oil	CS-M2
3. Air tank (Interior surface)	CS-M3
4. Underground, immersion piping and fitting	
• Exterior surface	
- Piping	CS-M7
- Fitting	CS-M8
• Interior surface	CS-M19
5. Miscellaneous Equipment including exposed carbon steel pipe with operation temperature below 93	CS-M15
6. Surfaces in Contact with Water	CS-M19
7. Turbine and Generator Steel Part, Oil Type Transformer (exterior surface for main tank and conservator) including Powerhouse Crane	CS-M20
7. Electrical Equipment, Cubicles, Panels and Boards	
- Exterior surface	CS-E1
- Interior surface	CS-E2

Paint system designations shall be referred to the Coating System Data Sheets as follow:

COATING SYSTEM DATA SHEET SYSTEM CS – M1

DESCRIPTION: - Structural Steel for Powerhouse and other buildings
- Non-embedded exterior surface of penstock

SURFACE PREPARATION: SSPC-SP10 Near White Blast Cleaning
Profile depth 25 to 65µm or as recommended
by paint manufacturer

<u>COATING</u>	<u>MIN. DFT.</u>	<u>SPECIAL NOTES</u>
FIRST COAT	60-80 µm.	Inorganic zinc with a minimum of 84 percent zinc by weight in the dry film
SECOND COAT	110-125 µm.	Epoxy coat
THIRD COAT	50-60 µm.	Acrylic aliphatic polyurethane
Total Dry Film Thickness is not less than 240 µm.		

COATING SYSTEM DATA SHEET SYSTEM CS –M2

DESCRIPTION: Surfaces in Contact with Oil

SURFACE PREPARATION: SSPC-SP5 White Metal Blast Cleaning
Profile depth 50 to 100 µm or as recommended
by paint manufacturer

<u>COATING</u>	<u>MIN. DFT.</u>	<u>SPECIAL NOTES</u>
FIRST COAT	100-125 µm.	Epoxy Phenolic
SECOND COAT	100-125 µm.	Epoxy Phenolic
THIRD COAT	100-125 µm.	Epoxy Phenolic

Total Dry Film Thickness is not less than 250 µm.

COATING SYSTEM DATA SHEET SYSTEM CS –M3

DESCRIPTION: Air Tank (Interior surface)

SURFACE PREPARATION: SSPC-SP10 Near White Blast Cleaning
Profile depth 25 to 65µm or as recommended

by paint manufacturer

<u>COATING</u>	<u>MIN. DFT.</u>	<u>SPECIAL NOTES</u>
FIRST COAT	50-100 μ m.	Epoxy coating
SECOND COAT	50-100 μ m.	Epoxy coating (If required)

Total Dry Film Thickness is not less than 100 μ m.

COATING SYSTEM DATA SHEET SYSTEM CS – M7

DESCRIPTION: Underground and Immersion Piping (exterior surface)

SURFACE PREPARATION: SSPC- SP10 Near White Metal Blast Cleaning
Profile depth 50 to 100 μ m or as recommended
by paint manufacturer

OVER WRAPPING: 50%

<u>COATING</u>	<u>MIN. Tape Thickness.</u>	<u>SPECIAL NOTES</u>
PRIMER		
INNER LAYER	0.5 mm.	Protective tape coating
OUTER LAYER	0.75 mm.	Protective tape coating

Coating specification accordance with AWWA C214.

Total Coating Thickness is not less than 2.5 mm.

COATING SYSTEM DATA SHEET SYSTEM CS – M8

DESCRIPTION: Underground and Immersion Fitting (exterior surface)

SURFACE PREPARATION: SSPC-SP 10 Near White Metal Blast Cleaning
Profile depth 50 to 100 μ m or as recommended
by paint manufacturer

OVER WRAPPING: 50%

<u>COATING</u>	<u>MIN. Tape Thickness.</u>	<u>SPECIAL NOTES</u>
PRIMER		
INNER LAYER	0.75 mm.	Protective tape coating
OUTER LAYER	0.75 mm.	Protective tape coating

Coating specification shall be accordance with AWWA C209.

Total Coating Thickness is not less than 3 mm.

COATING SYSTEM DATA SHEET SYSTEM CS – M15

DESCRIPTION: - Miscellaneous Mechanical Equipment
- Exposed Carbon Steel Pipe with operation temperature below 93 °C

SURFACE PREPARATION: SSPC-SP10 Near White Blast Cleaning
Profile depth 25 to 65µm or as recommended
by paint manufacturer

<u>COATING</u>	<u>MIN. DFT.</u>	<u>SPECIAL NOTES</u>
FIRST COAT	50 µm.	Epoxy Primer
SECOND COAT	50-60 µm.	Acrylic aliphatic polyurethane

Total Dry Film Thickness is not less than 100 µm.

COATING SYSTEM DATA SHEET SYSTEM CS – M19

DESCRIPTION: Surfaces in Contact with Water

SURFACE PREPARATION: SSPC-SP10 Near White Blast Cleaning
Profile depth 25 to 65µm or as recommended
by paint manufacturer

<u>COATING</u>	<u>MIN. DFT.</u>	<u>SPECIAL NOTES</u>
FIRST COAT	60-80 µm.	Zinc-rich primer
SECOND COAT	280-300 µm.	Epoxy (1-3 layer)

Total Dry Film Thickness is not less than 360 µm.

COATING SYSTEM DATA SHEET SYSTEM CS – M20

DESCRIPTION: - Turbine and Generator Steel Part
- Oil Type Transformer (exterior surface for main tank and conservator)
- Powerhouse Crane

SURFACE PREPARATION: SSPC-SP10 Near White Blast Cleaning
Profile depth 25 to 65µm or as recommended
by paint manufacturer

<u>COATING</u>	<u>MIN. DFT.</u>	<u>SPECIAL NOTES</u>
FIRST COAT	60-80 µm.	Zinc rich epoxy
SECOND COAT	100-150 µm.	Epoxy Coating
THIRD COAT	50-60 µm.	Acrylic aliphatic polyurethane

Total Dry Film Thickness is not less than 220 µm.

Noted: 1) Final shop painting shall not be applied within 100 mm of field welding. These areas will only receive one coat of inorganic, zinc-rich primer that can be removed prior to welding.

2) All components shall be from the same manufacturer and the manufacturer's instruction shall be rigidly adhered to.

COATING SYSTEM DATA SHEET SYSTEM CS – E1

DESCRIPTION: Electrical Equipment (Exterior surface)

SURFACE PREPARATION: SSPC-SP6 Commercial Blast Cleaning
Profile depth 50 µm or as recommended by coating manufacturer

<u>COATING</u>	<u>MIN. DFT.</u>	<u>SPECIAL NOTES</u>
FIRST COAT	50-125 µm	Epoxy primer
SECOND COAT	50-60 µm	High gloss Acrylic aliphatic polyurethane

Total Dry Film Thickness is not less than 110 µm.

Noted: Powder coating system is acceptable

COATING SYSTEM DATA SHEET SYSTEM CS – E2

DESCRIPTION: Electrical Equipment (Interior surface)

SURFACE PREPARATION: SSPC-SP6 Commercial Blast Cleaning
Profile depth 50 µm or as recommended by coating manufacturer

<u>COATING</u>	<u>MIN. DFT.</u>	<u>SPECIAL NOTES</u>
FIRST COAT	50-60 µm.	Epoxy primer
SECOND COAT	50-60 µm.	Low gloss acrylic aliphatic polyurethane

Total Dry Film Thickness is not less than 110 µm. (Second Coat not included)

Noted: Powder coating system is acceptable

TG-15 GALVANIZING

15.1 Where called for in the specifications, all materials and fittings shall be hot-dip galvanized after fabrication in accordance with ASTM A123. The weight of zinc coating per square meter of actual metal surface shall not be less than 0.60 kg. All galvanized structural steel shall be chromate coated.

15.2 All galvanized members shall be free from burrs, sharp edges, lumps and dross, and shall be smooth so that interconnecting parts will fit properly and parts may be assembled and disassembled readily. No machine or shop work, die work, punching, welding, etc, will be allowed after galvanizing, except the tapping of threads and clearing of holes.

15.3 The preparation for galvanizing and galvanizing itself shall not adversely affect the mechanical properties of the coated material.

15.4 Tubular members shall be provided with drainage holes.

15.5 Galvanizing areas damaged during shipping and/or installation shall be repaired using galvanizing touch-up paint.

15.6 Galvanized material shall be subject to tests as outlined in ASTM A123.

TG-16 PACKING

16.1 All the Equipment shall be carefully packed in accordance with the conditions outlined in GC-13.7. The same precautions and care shall be taken for equipment (including components) which cannot be packed or crated.

16.2 Machine finished surfaces of the equipment and the portions to be embedded in concrete shall be adequately protected by corrosion preventive means, as specified in TG-14.

16.3 The commissioning parts shall be packed and crated firmly to withstand storage for a long time, and those in need of rust-preventive treatment shall be so treated.

16.4 The commissioning parts shall be packed separately from other articles and absolute care shall be taken to prevent commissioning parts being packed or crated in the same box or crate with the equipment for the installation materials. Packages of commissioning parts shall carry notation in accordance with the conditions outlined in SC-7.4, which clearly identifies that the contents are commissioning parts and shall be accompanied by a list of contents which sets forth directions for storing.

TG-17 LUBRICANTS

17.1 The Contractor shall submit to the Engineer for approval a list of proposed lubricants to be used on all the equipment specified in this Contract. All lubricating oils and greases not specified above shall be of a type generally available in Thailand.

17.2 Oil required for cleaning, flushing and testing of turbine and generator guide bearings, governor equipment and piping after installation shall be supplied by the Contractor.

TG-18 INSPECTION AND TESTS - ELECTRICAL/MECHANICAL

(a) General

All materials and equipment shall be subject to tests and inspection while in process of, and upon completion of manufacture. For each piece of material, component or equipment, the inspection and tests shall consist of:

- the relevant tests and inspection outlined in Clause GC-13 and GC-14

- the tests and inspection required by the relevant standards
- the tests and inspection as specified herein.

The Contractor shall submit to the Engineer certified copies of all test results. The results of each test shall be recorded in the form of test certificates or test reports as specified in SC-4.6.

The Contractor shall submit evidence to the Engineer that the instruments used for the tests have been calibrated at an approved testing laboratory within a period of up to three months for a portable instrument and six months for a fixed instrument.

The acceptance of factory inspection and tests shall not prejudice the right of the Engineer and EGAT to reject whole or part of the works if it does not comply with the Contract when erected on Site.

(b) Shop and Type Tests

All works shall be subject to type, sample and routine tests at the manufacturer's factory in accordance with this specification and the conditions outlined in Clause GC-13.

If facilities are not available at the manufacturer's factory to execute the tests specified, the Contractor shall state, at time of bid, what alternative arrangements will be made.

The Contractor may offer type test results for identical equipment in lieu of the type tests specified, in which case the Engineer may waive the specified type tests. If type test results for identical equipment are offered in lieu of the specified type tests, the Contractor shall also provide, to the Engineer, evidence as to the similarity of the equipment tested and the Contract equipment.

(c) Field Tests

(i) Responsibility for Tests

All tests to be executed at the Site will be performed by the Contractor under witness of EGAT and the Engineer.

The Contractor shall prepare and submit the detailed plan as outlined in Clause SC-4.6 for each item of tests specified in the technical specifications.

The detailed plan shall consist of test procedures including test recording sheets, test summary sheet, required testing equipment and man-hours required for preparation and execution of the tests. The detail plan and test procedure shall be subject to the approval of the Engineer.

The Contractor shall also prepare and submit the reports outlined in Clause SC-4.6 based on the test results. The Contractor, with advice from the Engineer and/or EGAT will be responsible for safety during the performance of all testing.

(ii) Instruments, Equipment and Materials for Tests

The Contractor shall provide all instruments and equipment for all site tests.

(iii) Scope of Tests

The tests to be carried out and passed before taking over of the Works by EGAT shall be deemed to comprise two main stages of testing as follows:

- Preliminary tests which are tests performed prior to rotation of, energizing at normal voltage or admission of normal water or air pressure to the main or auxiliary services under test.
- Tests on Completion, which are tests to prove progressively the correct operation of complete auxiliary systems and of the main works. These tests shall be carried out in accordance with the Conditions outlined in Clause GC-14.

(iv) Provisional Acceptance Tests

The Contractor shall carry out all testing in accordance with the conditions outlined in Clause GC-22.2.

(d) Mechanical and Electrical Requirements for Inspection and Testing**(i) Castings**

Refer to TG-7, paragraph 3(a).

(ii) Forgings

Refer to TG-7, paragraph 3(b).

(iii) Weldments

Refer to TG-12.

(iv) Pressure Tests

The Contractor shall give adequate notice of any proposed pressure tests. Free access to the testing equipment shall be allowed to the Engineer during the course of any test. The Contractor shall furnish the necessary copies of all pressure test reports on request.

All tanks, vessels and pressure containing components with maximum working pressure of 0.1 MPa gauge pressure or greater shall be pressure tested in accordance with the ASME Boiler and Pressure Vessel Code Section VIII, Division I.

All testing shall be by hydrostatic means, unless specifically authorized otherwise by the Engineer, preferably using fluid compatible with the pressure containing surfaces and with the intended service.

All test fluids shall be drained out after completion of satisfactory testing. Disposal of such fluids after field tests shall be in a manner approved by the Engineer. Where water has been used for testing, all wetted surfaces shall be immediately blown dry.

(v) Circuit Tests

All circuits shall be capable of being tested power frequency withstand for 1 min at the following voltages:

- 400 V power circuits 2200 V ac to ground
- 48 V dc circuits 1000 V ac to ground
- 230 V ac and control circuits 1500 V ac to ground

TG-19 RUBBER SEAL**19.1 General**

Rubber fluorocarbon seals and plain rubber seals shall be moulded seals, furnished by the Contractor, drilled, where required, shop assembled with the plant and match marked. Seal strips and corner seals shall be moulded in lengths suitable for obtaining the minimum finished length.

19.2 Characteristics

The rubber for the seals shall be compounded of natural rubber or a copolymer of butadiene and styrene, or a blend of both and shall contain reinforcing carbon black, zinc oxide, accelerators, antioxidants, vulcanizing agents and plasticizers. Physical characteristics shall meet the following requirements. The test methods shall meet the following requirements:

Physical Test	Test Value	Test Method Specification
Tensile strength	Min. 20.7 MPa	ASTM 0412-2006
Elongation at Break	Min. 450%	ASTM 0412-2006
300 % Modulus	Min. 6.2 MPa	ASTM 0412-2006
Durometer Hardness (Shore Type A)	60 to 70	ASTM 02240-2005
Water Absorption	Max. 5% by mass	ASTM 0471-2006
Compression Set	Max. 30%	ASTM 0395-2003
Tensile Strength (after oxygen bomb aging)	min 80% of tensile strength	ASTM 0572-2004

19.3 Curing

The rubber materials shall be properly cured in a manner to ensure a homogeneous cross section free from pitting, blisters, porosity, and other imperfections.

19.4 Fluorocarbon Sheath

The fluorocarbon sheath on the rubber fluorocarbon bonded seals shall be abrasion resistant Fluorocarbon Film No. 4508 from Huntington Rubber Corporation, Oregon, USA, or equivalent. The outside surface of the fluorocarbon sheath shall be free of adhering or bonded rubber. The fluorocarbon shall have the following physical properties:

- ultimate tensile strength (minimum) 13.8 MPa
- minimum elongation 250%

19.5 Test Pieces

Each piece of rubber fluorocarbon seal strip shall be moulded with sufficient excess length to provide test pieces for testing the adequacy of adhesion bond between rubber and fluorocarbon on the bulb. The tests for adhesion bond shall be conducted in accordance with the relevant standards, for strip specimens, with results showing a minimum adhesion bond value of 17.5 kN/m width for a separation at 25 mm per minute; or, the specimens may be

tested by a strip of 50 mm per minute (on a 25 mm wide specimen) by a minimum 140 N load applied at an angle of 90 degrees to the fluorocarbon. In either method of test, the stripping shall show tear of the rubber and not failure of the adhesion bond between the rubber and the fluorocarbon. Failure of any test specimen to meet the requirements of the test method will be cause for rejection of the piece from which the test specimen was taken.

19.6 Fitting Seals

The rubber seals shall be cut accurately to length and shall be attached to the equipment to the approval of the Engineer. Ends of seals shall be cut square and butted firmly together at joints. The seal clamp bars shall be used as templates for locating the holes in the rubber seals and the holes shall be drilled with a rotating tubular drill.

When cutting and drilling the seals the Contractor shall allow for shrinkage so that the seals may be fitted easily at Site without stretching, without producing gaps at joints and with the correct projection when required.

19.7 Spare Seals

Spare seals shall not be cut to length or drilled.

TG-20 CONSISTENCY OF SUPPLY

The Contractor shall ensure that all electrical and mechanical components and instrumentation such as, but not limited to motors, pumps, valves, relays, starters, indicating lights, meters, etc, are of a common manufacturer. This will ensure maximum interchangeability and minimize commissioning parts requirements.

TG-21 INSPECTION AND TEST FOR PIPING

Before testing, all anchor blocks, thrust supports, hangers and braces shall be in place.

All piping systems shall be flushed clean prior to testing. Oil and hydraulic piping shall be flushed using the same fluid for which the system is designed.

On completion of erection and preparation for testing, all piping systems shall be subject to final inspection by EGAT to ensure compliance with the requirements of the relevant codes and standards and this specification.

On conclusion of satisfactory inspection, all piping shall be hydrostatically tested to 1.5 times the design pressure, in accordance with the provisions of all applicable codes. Piping under test shall show no leakage during the time required for inspection of joints and connections, and test pressure shall be maintained without loss for a period of 30 minute.

For pneumatic tests, where required, the test pressure shall be 1.3 times the maximum operating pressure of the system withstand 30 minutes. Care shall be exercised when applying the test pressure. The pressure of the system shall be gradually increased to not more than one-half of the test pressure. Thereafter, the pressure shall be increased in steps of approximately one tenth of the test pressure until the required test pressure is reached.

No peening or caulking of leaking joints will be allowed.

In addition, all pipelines shall be subject to flow tests to ensure that passages are free from obstruction.

The pipeline or section of line to be tested in each individual test shall be approved by EGAT. Blanks or blind flanges shall be installed by the Contractor and shall not be removed until line is extended. Proper means of venting air shall be provided to ensure that the test is effective. All pressure relief valves shall be removed before testing and blank flanges or plugs installed. None of test shall be performed against a closed valve.

Defective joints shall be repaired as follows.

- Soldered joints which leak shall be disassembled, cleaned, reassembled, refluxed and resoldered. Soldered joints shall not be repaired by brazing.
- Brazed joints which leak shall be repaired by cleaning the exposed area, refluxing and rebrazing.
- Welded joints which leak shall be repaired in accordance with ANSI B31.1 if approval given by EGAT.
- Threaded joints which leak shall be unscrewed and remade.
- Flanged joints which leak shall be reassembled with a new gasket.
- Mechanical coupling joints shall be reassembled with a new ring.

On completion of repairs to defective joints, a retest shall be carried out to demonstrate the effectiveness of the repairs.

After Testing. All piping systems shall be cleaned and flushed after installation and testing by EGAT. Water piping systems shall be blown dry with air after successful completion of hydrostatic testing. The method, materials and supervision shall be to the acceptance of EGAT.

TG-22 CLEANING AND FLUSHING OF OIL AND HYDRAULIC PIPING

Cleaning and flushing of hydraulic piping shall as a minimum conform to the general requirements outlined in ASTM D4174, "Standard Practice for Cleaning, Flushing and Purification of Fluid Hydraulic Systems".

All shop fabricated piping shall be cleaned of all rust, scale, oxide films, weld materials by non-electrolytic acid pickling to SSPC-SP8. Where piping is further fabricated at the Site (including in its final location) and such fabrication involves welding or other processes detrimental, in the opinion of EGAT, to the cleanliness of the piping system, the Contractor shall perform pickling of the piping system or sub-systems, or employ other means approved by EGAT, to ensure such cleanliness. Valves and other line-mounted devices shall be of equal cleanliness to the piping when installed and means for achieving same shall be approved by EGAT.

Notwithstanding the above, the Contractor shall submit detailed procedures covering the pickling, cleaning and flushing of all hydraulic and lubricating oil piping systems at the shop prior to commencement of any fabrication work. It is the Contractor's responsibility to ensure that all such piping is adequately cleaned for the intended service, and the Contractor shall propose such additional methods not specified above which may be required to achieve this. The Contractor shall ensure flushing oil temperature is at 550C minimum for flushing oil systems.

The Contractor shall supply all plant and materials required, including tanks, pumps, heaters, cross connecting pipes, hoses, valves, chemicals, and cleaning solutions.

TG-23 QUALITY ASSURANCE AND QUALITY CONTROL

TG-23.1 GENERAL

This section covers the requirements of quality assurance and quality control for the project. Contractor's Quality Manager shall be responsible for all QA/QC for this project and shall report to, and be accountable only to, The Contractor's Project Manager.

The Contractor shall develop and implement an effective Project Quality Program for the Project so as to ensure that all project activities and functions are in full compliance with the requirement of all contractual conditions, applicable specifications, and standards.

The Project Quality Program shall be implemented and covered the following elements:

- Quality Policy
- Quality Management
- Quality Systems
- Quality Control
- Quality Assurance

The Quality Program shall incorporate and encompass all of these important elements. A Project Procedure shall be developed which shall be followed in all aspects of the Work to properly implement the Quality Program.

The range of the Project Quality Program shall extend from the administration and management of the project through the engineering and design activities, including procurement of major equipment and materials, minor materials and supplies, and extend to construction, erection, installation, and complete with testing and commissioning of the units. Every item, action, and function of work shall be covered by the Quality Program.

TG-23.2 PROJECT QUALITY MANUAL

As a means of assuring that the performance of each phase of the Work fulfills the requirements of the Contract Documents, the Contractor shall provide and implement a documented Quality Program for the Work (Project Procedure). The Program shall be capable of providing assurance that all project activities and functions including, but not limited to, engineering and design, purchasing, manufacturing, shipping, storage, erection, construction, testing, examination, and commissioning of all equipment, materials, and services comply with the requirements of the Contract Documents. This Procedure shall incorporate, but shall not be limited to or by, the details provided and referenced herein. The Quality Program shall be acceptable to EGAT.

The Contractor's Quality Program shall be based upon, shall implement all provisions of, and shall meet all requirements of ISO 9001, "Quality Management System-Requirements". Details and features of other successful quality programs shall be used as guides, as acceptable, for those areas not necessarily covered by the above referenced standards or requiring supplementation. Those areas of work within the Project which are limited within or outside the scope of the ISO standards, such as quality in project management and administration, engineering and design, and others, shall be based on acceptable other implementations of quality programs covering similar work areas.

The Contractor shall demonstrate its preliminary compliance with these requirements initially in one of the following ways:

- Submitting a copy of their Quality Management Manual which includes their Certificate of Registration to ISO 9001 issued by a recognized Registrar, or
- Submitting their Quality Management Manual with an independent evaluation demonstrating ability to meet ISO 9001 requirements through implementation of their Quality Program and/or additional procedures.

Additionally, the entire Quality Program shall be developed and implemented in a form and manner as acceptable to EGAT. EGAT may, at its sole discretion, participate in any portion and/or part of the Quality Program activities throughout the duration of the Work. The program implementing the requirements of ISO 9001 shall provide for all features where EGAT involvement and participation and/or notification or review is stipulated or inferred to the maximum extent. Such EGAT participation shall be a right which shall be implemented and accommodated by the Contractor to EGAT's satisfaction. In all parts of the ISO 9001 documents where reference is made or inferred that a provision of the requirements is applicable if contractually required, such contractual requirement shall exist just as if it is stated herein and shall be made a part of this Contract and a full part of the requirements of the Contractor under this Contract.

The Contractor's Quality Program shall be documented in a Project Quality Manual or Project Quality Plan which included and uncontrolled copy of the Contractor's Quality Management Manual.

The form and format of the Project Quality Manual or Project Quality Plan and Program shall be acceptable to EGAT. Provisions, concepts, and requirement of ISO 9001, ISO 9004 and these contract documents shall be the basis and guideline for the Project Quality Manual and implementation of the Quality Program.

The Project Quality Manual shall describe the authority and responsibility of the persons in charge of the Project Quality Program and inspection activities. Personnel responsible for quality assurance and control shall be independent of project responsibilities and shall have the authority to identify and obtain corrective action in response to quality concerns.

Controlled copies of the Project Quality Manual or Project Quality Plan shall be submitted to EGAT. Project Quality Manual or Project Quality Plan shall be kept current by submittal of revisions as applicable throughout the life of the Contract.

TG-23.3 MISCELLANEOUS REQUIREMENTS

Project Quality Manual or Project Quality Plan shall include his quality organization chart, with names, location, and telephone numbers, indicating also alternates and specific responsibility for each person, and uncontrolled copy of the Contractor's Quality Management Manual.

As part of progress reporting, the Contractor shall submit monthly, the inspection and test status of major equipment. The Contractor shall submit a schedule of his materials and equipment testing program to EGAT in accordance with scheduling requirements.

Shop test reports/records of all tests issued by the manufacturer shall be prepared and submitted to EGAT for review and acceptance within 30 days after each shipment according to the requirements in Section SC-4.7

TG-23.4 COMPLIANCE – NONCOMPLIANCE

The Project Quality Program shall inherently be designed, established, and implemented to identify noncompliance early in any phase of the Work so that such noncompliance shall be eliminated and avoided. The process shall inherently provide for the replacement of nonconforming designs, specifications, materials, construction, or other work with work that conforms.

TG-23.5 TESTING LABORATORY

In case of disagreement regarding the conformity of material or equipment to the specification. Contractor shall employ an independent (meaning other than an affiliate, subsidiary, or interlocked directorate of Contractor or any other similar association) testing laboratory (test lab) that acceptable to EGAT at Contractor's expense to conduct lab or field testing in order to confirm the quality of those material or equipment supplied by The Contractor if qualities are found inferior to specification and/or EGAT's requirements.

All test specimens for testing shall be taken by the test lab.

Contractor shall instruct the test lab to provide three copies of the test results and reports directly to EGAT.

Contractor shall ensure that employed independent testing laboratory does not reassign or sublet any portion of their contracted testing work.

EGAT shall be provided timely access to the test lab's facilities for witnessing of tests. Employment by Contractor of a test lab shall in no way relieve Contractor of any obligation set forth in this Contract.

TG-23.6 MANUFACTURERS AND SUPPLIERS

Contractor shall procure all major material items for the Project from sources acceptable to EGAT. Contractor shall seek and obtain notifications of EGAT's acceptance of Contractor's material and equipment sources in writing. Such acceptance shall not relieve Contractor of any obligation under this Contract to meet all requirements of the contract documents.

In case of the country of the manufacturing or assembly plant of the equipment proposed by Contractor is not country of origin and/or EGAT has never supplied by such manufacturer, EGAT reserves the rights to audit such manufacturing or assembly plant. If the audit result is unacceptable, the Contractor shall resubmit the new manufacturing or assembly plant which is qualified and accepted by EGAT.

Contractor shall ensure that purchase orders to manufacturers and suppliers contain all the applicable standards and specifications in accordance with these contract documents.

Contractor shall ensure that purchase order(s) to approved manufacturers and suppliers are not reassigned or subcontracted to other manufacturers and suppliers without EGAT's written acceptance. Any further manufacturers and suppliers subcontracted in consequence of approved manufacturers and suppliers may be permitted upon case by case consideration as requested by EGAT. The manufacturers and suppliers which are requested for approval shall obtain the Certificate of ISO 9000 series or other acceptable to EGAT of international standards of application in order to assure the quality of equipment and material to be supplied.

Contractor shall ensure that manufacturer and supplier develop and implement quality control plan/inspection and test plans for each major material and equipment.

All the requirements stated below shall be stipulated in purchase orders or purchase contracts placed by Contractor on a supplier and by the letter on sub-suppliers for equipment and materials. The same shall apply to Contractor if Contractor is a supplier of equipment and materials:

EGAT reserves the right to perform plant evaluation assessment (survey), quality assessment (audit), surveillance activities, and to inspect equipment and materials at the Supplier's facility to verify compliance with the terms and conditions of the purchase order and its related documents at any time and to witness any and all tests. EGAT reserves the right to perform such visual examination (inspection) at the Supplier's facility as EGAT deems necessary including, but not limited to, those related to workmanship, materials, surface defects, component dimensions and paint specification. EGAT reserves the right to require certificates and data from the Supplier and any pertinent aspect of the manufacturing process including, but not limited to, mill test reports, heat treatment certificates, welders and welding procedure qualification records, test records, and quality control document (manuals) that will form part of the nonmaterial requirement that shall be shipped with the materials as a "document package". It is Contractor's responsibility to ensure that all requirements including the "document package" are complied with and provided by his supplier. These quality criteria requirements do not relieve The Contractor and Contractor's supplier of their contractual responsibilities for quality and its control.

TG-23.7 EGAT RIGHTS

EGAT shall have the sole authority for accepting or rejecting nonconformance dispositions and nonconforming materials or equipment. Contractor's work and related records shall be subject to inspection by EGAT, the Engineer and/or EGAT Inspector Representative to assure compliance requirements. A request for corrective action may be issued by EGAT upon detection of a noncompliance with the requirements of the contract documents and/or the accepted Quality Program. The Contractor shall correct in a timely manner all such deficiencies so identified and shall notify EGAT of such correction by written notice.

EGAT reserves the right to conduct schedule and unscheduled quality assessment of Contractor's quality system, project operation, and project quality plan implementation. The results of such assessments (audits) shall be confidential between Contractor and EGAT. Should EGAT exercise its right to perform quality assessment (audit), Contractor will be given a minimum of 14 calendar days notice. Contractor shall provide all access and assistance in a timely manner to EGAT personnel who will perform the quality assessment (audit). Contractor shall implement corrective action on all deficient areas discovered during the quality assessment (audit) within a mutually agreeable time frame. All costs incurred during the quality assessment (audit) shall be borne by Contractor.

Similarly, EGAT audit right shall prevail on Contractor's suppliers in accordance with these contract documents.

End of Chapter

TECHNICAL SPECIFICATIONS
MECHANICAL EQUIPMENT

LAMTAKONG HYDROPOWER PROJECT**TECHNICAL SPECIFICATION – MECHANICAL EQUIPMENT****TABLE OF CONTENTS**

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TM-1 TURBINE

EQUIPMENT WORKS

MECHANICAL EQUIPMENT - TECHNICAL SPECIFICATIONS

TM-1 TURBINE

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TM-1 TURBINE

TM-1.1 GENERAL

These specifications do not specify in complete details the various components of the turbine. This is left to the experience and practice of the Contractor who shall furnish turbine equipment, which shall meet in all respects the specified requirements in regard to performance, durability and satisfactory operation. However, certain features, material and design requirements are specified.

The required performance and principal parts of the turbine are set forth in the following subsections, which outline the general features to be incorporated in the design. Any deviations from these specified requirements shall be approved by EGAT.

TM-1.2 TYPE AND DESCRIPTION

The turbine shall be Reaction Type. The turbine speed shall be proposed by the Contractor .

The proposed turbine equipment shall be consisted of complete set of spiral case or inlet casing, operating mechanism, guide vane and servomotor. Such equipment shall be of assembled in one unit to minimizes the number of components, size and site installation work. The equipment shall have movement testing and hydro testing at manufacturer work shop.

Provision shall be made to install and maintain the turbine and all assembly parts without powerhouse crane. Necessary lifting and set-down devices for handling with mobile crane (if applicable) shall be provided. The Contractor shall propose the procedure for installation of the turbine and/or generator with alignment method in his Bid proposal as well as procedure of assembly and disassembly to be done during maintenance period.

The computational of prototype performance shall be submitted within 3 months after issuance date of Letter of Intent, at least consist of:

- Model hill chart
- Runaway Speed curve
- Critical cavitation coefficient
- Model acceptance test results or mathematical model
- Scale up efficiency, dimension and etc.
- Calculation for prototype Unit GD^2 according to site condition.

TM-1.3 DESIGN DATA

The turbine shall be designed to operate in the ranges as specified below. The water level elevations and net heads on the turbine are as follows:

Water Surface Elevation

Reservoir

- Maximum water level	280.30	m MSL
- Normal water level	277.00	m MSL
- Design water level	271.50	m MSL
- Minimum water level	252.60	m MSL

Tailwater

- Maximum tailwater level	247.40	m MSL
- Normal tailwater level	246.13	m MSL
- Minimum tailwater level	245.39	m MSL

1) Net Head

- Maximum net head (not lower than)	34.65	m
- Rated net head	24.14	m
- Minimum net head (not higher than)	18.82	m

2) Flow Variation

The rated discharge under rated net head is 7.96 m³/s. The maximum and minimum water discharge shall be proposed by the Contractor. The Contractor shall propose the minimum water discharge, which generate the minimum turbine output not greater than 30% of the rated turbine output under all net head. The Contractor shall propose the maximum water discharge under rated net head and maximum net head, which generate output at 100% of the rated turbine output.

3) Turbine center line level To be proposed by Contractor

4) Turbine speed To be proposed by Contractor

TM-1.4 SPEED RISE, PRESSURE RISE, INERTIA, RUNAWAY SPEED, CRITICAL SPEED AND MAXIMUM PRESSURE

The moment of inertia of the generating unit and closing time of guide vanes should be so selected that maximum momentary speed rise of unit shall not exceed 60% of rated speed for Francis Turbine and shall not exceed 80% of rated speed for Kaplan Turbine and pressure rise shall not exceed 49.50 m water column at the turbine inlet. The turbine manufacturer shall coordinate with the generator manufacturer to achieve desired fly wheel affect.

The maximum runaway speed shall be stated and guaranteed by the supplier. All rotating parts and bearings shall be capable of withstanding continuously the runaway speed attached with guide vanes fully open and the generator disconnected and unexcited and with gross maximum head on turbine, without any damage to its parts for every such occurrence provided that the cooling arrangement are functional and for 5 minutes.

The turbine shall be designed to have a wide margin of safety between critical speed and the rated speed, overspeed and the maximum runaway speed. The first critical speed shall be at least 10 percent above the maximum runaway speed. The Contractor (by the turbine manufacturer) shall check the critical speed and torsion vibration characteristics of the combined rotating parts of the generating unit after determining the necessary data from the generator manufacturer excessive or unreasonable torsion vibration under any conditions shall be avoided.

The design of the stationary parts of the turbine shall be such that resonance will not occur at any rotational speeds (rated speed, transient overspeed and runaway speed).

TM-1.5 TURBINE OUTPUT AND TURBINE EFFICIENCY

The Contractor shall responsible for design, manufacture, install and test the turbine in associated with the direct coupled generator or speed increaser capable to deliver the power delivered as specified in TE-2.1.1

TM-1.5.1 Turbine Output

The rated output of the turbine under rated net head of 24.14 m. shall not be less than 1,732 kW.

Remind that, If the guarantee for power delivered cannot archive (from field test), the guarantee efficiency of turbine is expected to fail. On the failure of efficiency, the Contractor shall conform the SC-6.4.2 Guarantee for Power Delivered.

TM-1.5.2 Turbine Efficiency

Before commencing manufacturing of the turbine, the efficiency of the turbine shall be determined by mathematical model or physical model tests in the Contractor's laboratory or in another laboratory acceptable to EGAT using the procedures as recommended in IEC Publication No. 60193.

The efficiency of turbine under rated output and rated net head of 24.14 m shall be proposed and guaranteed by the Contractor . The guaranteed turbine efficiency shall not be less than 92%.

Prototype efficiency shall be stepped-up from the measured model efficiency according to IEC 60193. The increment of step-up shall be calculated only for the maximum efficiency point, this calculated step-up shall then be applied as a constant for all other operating points (parallel step-up).

On failure of turbine efficiency to meet the guaranteed efficiency, the Contractor, at his decision, may perform the field efficiency test for turbine at his own cost. If field efficiency tests are performed, the results of the field test shall govern. The contractor shall conform to SC-6.4.3 Guarantee for Turbine Efficiency.

The Contractor shall submit the turbine model hill chart and the prototype turbine performance characteristics (Hill Curves) in his bid proposal. The curves shall have the turbine discharge along the vertical axis and net head along the horizontal axis. Lines of constant turbine output in kW, percentage of guide vane opening and any limits of operation imposed by cavitation or vibration shall be superimposed on the diagram.

TM-1.6 CAVITATION GUARANTEE

The Contractor shall guarantee that the pitting due to cavitation during a period of not less than 8,000 operating hours from the Provisional Acceptance shall not impair the strength of the runner or be measurably detrimental to the efficiency or turbine output.

The amount of material that may be lost by the runner due to the cavitation during this period, in kilograms of material, shall not exceed 1.5 times the square of the discharge diameter of the runner in meters. The amount of material that may be lost by the discharge ring and other parts shall not exceed 0.5 times the square of the discharge diameter of the runner in meters. In addition, the metal thickness of the runner or other parts shall not be reduced due to pitting during this period by more than an average of 3 mm over any single, continuous area of 0.10 m² or more. The guarantee shall be based on the following conditions.

- a) The turbine shall not be operated for generation more than 10 percent of the operating time at output less than the minimum stated or more than 50 hours at output greater than the maximum output specified in the “Guaranteed Characteristics” of the Bid.
- b) The tailwater level shall not be less than the minimum specified elevations, except during unit start-up.
- c) Wear due to erosion by suspended matter in water or corrosion caused by chemical composition of water is not intended to be covered by the cavitation guarantee.

If the runner fails to meet the above guarantee, the Contractor shall repair all pitted areas in a satisfactory manner by welding. The final repaired surfaces shall have stainless steel overlay with a minimum finished thickness of 3 mm. The Contractor shall also make the necessary alterations to solve the causes of this pitting or shall replace the runner with new one, which is satisfactory. The Contractor shall be fully responsible for the works of de-watering inside draft tube, dismantling, pitting rectification and reinstallation. Subsequent to repair, the runner shall be subject to the above pitting guarantee for another period of 8,000 operating hours. The guarantee shall be renewed each time the runner to meet the guarantee. If the turbine runner fails to meet the pitting guarantee after repairs have been effected three (3) times, the Contractor shall supply a new runner with an improved design and shall bear all costs of runner supply.

TM-1.7 QUALITY OF WATER

After signing of the Contract, the Contractor is obliged to check the quality of water taken from the reservoir by his means and expenses. The results of reservoir water analysis shall be taken into account by the Contractor when selecting materials for all equipment supplied by him.

TM-1.8 RUNNER

The runner, including the runner cone, shall be casting or fabricated construction of stainless steel, according to ASTM 743 Grade CA-6 NM, EN 1.4313 (X3CrNiMo13-4) or GX4CrNi13-4. The proposed other material standard shall not be accepted. The runner material shall be of the type which can be repaired by welding satisfactorily at site without the need for other than local heat treatment.

The hydraulic shape of the runner vanes shall be designed to obtain the best possible results taking into consideration of cavitation and efficiency. Its design also shall precisely conform

to the model design within the tolerances set out in the International Code for Model Acceptance Tests of Hydraulic Turbines, IEC Pub. 60193, chapter IV, and the runner shall be carefully surveyed by an approved method to prove this to the satisfaction of the EGAT. Before shipment, the Contractor shall submit proof that the finished runner contours and shape agree with the design requirements.

The surface of the runner in contact with water shall be ground to a smooth and even surface without any humps or hollows.

All runner welds shall be fully penetrated and furnace stress relieved. The Contractor shall provide copies of the certified time-temperature record for furnace stress relieving. The surface of the runner in contact with water shall be ground to a smooth and even surface without any humps or hollows.

The runner wearing rings shall be provided, and may be either replaceable or integrated in the runner. They shall be of different composition from the stationing rings provided on the head cover (front cover) and bottom ring (rear cover) and the difference in hardness between the rotating and stationary rings shall be at least 50 Bhn (rotating rings are harder).

The runner shall be connected to the shaft by through-bolts with nuts and locking devices. The coupling bolt holes in the runner shall be line reamed with the runner and shaft assembled. The fit of the bolts shall be in accordance with the minimum values shown in the most recent issue of ANSI/IEEE 810.

Provision shall be made to permit aeration of the draft tube should operating experience show this to be necessary or desirable.

TM-1.9 SPIRAL CASE/ INLET CASING

The contractor shall propose either a spiral case or an inlet casing depending on the turbine type.

A manhole shall be provided at the turbine inlet (inlet valve downstream side). In case of no inlet valve, a manhole shall be provided at the inlet casing. The purpose is used for inspection and maintenance inlet valve. Manhole is comprised with hinged cover opening outward into the access water passage, handle, jackle bolt, o-ring. Inner surface of manhole shall be conform to the contour of turbine inlet.

At least a drain valve with hand wheel, at least 150 mm diameter shall be provided at spiral case/inlet casing to drainage pit. All pipe, valves and fittings shall be at least PN6.

TM-1.9.1 Spiral Case

The spiral case shall be made of steel or carbon steel plates welded to the stay ring with stay vanes of plate construction. Design and fabrication of the spiral case shall be in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, Division I. Under this design pressure, the hoop stress due to maximum internal pressure, computed in accordance with the Foppl Formula expressed as follows shall not exceed the stress recommended in the ASME Boiler and Pressure Vessel Code, Section VIII, Division I:

$$F = \frac{p \cdot r}{e} \cdot \frac{(R+a)}{2a} \cdot t$$

Where

- R Radius from centerline of the unit to centerline of spiral case section under consideration (mm.)
- a Inside radius from centerline of unit to point on spiral case section under consideration (mm.)
- r Inside radius of spiral case section under consideration (mm.)
- t Thickness of material at point under consideration (mm.)
- p Maximum internal design pressure (MPa)
- e Joint efficiency as given in the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Unfired Pressure Vessels.
- F Stress in materials at point under considerations (MPa)

The circumferential joints shall be designed to give a strength equivalent to that of the longitudinal joints of corresponding sections. A corrosion allowance of 2 mm thickness shall be added. Welds in spiral casing shall be inspected by dye-penetration test / ultrasonic test wherever necessary.

The spiral case shall be provided with the equipment and accessories, according to IEC62006, Hydraulic machines – Acceptance tests of small hydroelectric installations or the following equipment and accessories:

- Flange and dismantling joint.
- Dismantling joint towards the inlet valve.
- All support, mounting feet (frame), lifting lugs, leveling jacks for erection and necessary devices to anchor the spiral case during concrete work and necessary grounding holes.
- Four (4) piezometer taps equally spaced around the spiral case inlet pipe for measuring net head. The location determined by the Contractor shall be subject to the EGAT for approval.
- Four (4) Winter-Kennedy piezometer taps for flow measurement. The location determined by the Contractor shall be subject to the EGAT for approval.
- A gauge pressure indicating transducer and transmitter at the distributor centerline elevation. This shall give a 4-20 mA signal over a range of 0-100 m head.

- At least a 50 mm (min.) diameter drain connection at the lowest point for drainage of the spiral case.

TM-1.9.2 Inlet Casing

The inlet casing shall be made of fabricated mild steel with a flange connection to the outer distributor ring and to the power conduit liner.

The Contractor has to define the limit of the steel. A drainage pipe and valve for dewatering the inlet section shall also be provided.

The circumferential joints shall be designed to give a strength equivalent to that of the longitudinal joints of corresponding sections. A corrosion allowance of 2 mm thickness shall be added.

The turbine inlet pipe to be connected to the penstock shall be exposed from the powerhouse wall not less than 1 m.

Upstream end of the turbine inlet pipe shall be well prepared to facilitate welding to the downstream end of the penstock.

The Inlet casing shall be provided with the equipment and accessories, according to IEC62006, Hydraulic machines – Acceptance tests of small hydroelectric installations.

TM-1.10 PRESSURE RELIEF VALVE (PRV) AND/OR EXTERNAL FLYWHEEL (IF APPLICABLE)

If applicable, pressure relief valve (PRV) and/or external flywheel shall be provided in order to control both maximum overspeed of the machine and maximum hydraulic pressure in the penstock within the specified guarantee values. The proposal of surge tank shall not be accepted. The solution selected by the Contractor shall be proposed in his Bid Proposal with all hydraulic transient calculation sheets (the guarantee values proven), working descriptions and schematic diagram of the selected equipment including the equipment structure and layout. In addition, the price of selected solution shall be quoted clearly in the Price Schedule.

If PRV is proposed, it shall be installed at either inlet of spiral case depending on the manufacturer's design and shall be automatically opened to the atmosphere or outlet pipe if a fast closure of the guide vane occurs. This relief valve shall be immediately opened during the fast guide vane operation. After the end of the guide vane closure, the relief valve shall be slowly closed.

PRV shall be operated by means of governor main distributing valve, against the maximum head and water discharge with normal working stresses in all parts. The fluid velocity in the hydraulic oil system shall not exceed 4 m/s.

The opening/closing time shall be designed by Contractor /manufacturer to achieve the pressure rise and speed rise control.

PRV shall be designed for the following conditions.

- | | |
|---------------------------|--|
| – Maximum design pressure | Not be less than 1.1 times of maximum pressure in penstock |
| – Maximum pressure in PRV | To be estimated and guaranteed by turbine manufacturer but not be less than 49.50 m (TM-1.4) |

All parts subject to the maximum hydraulic pressure shall be in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, Division 1. The allowable stresses for non-pressurized steel parts shall not exceed the values of the AISC Specifications for the design, fabrication and installation of structural steel for buildings.

In the design of the hydraulic cylinder and piping, the allowable stresses under maximum pressure, including water hammer, shall not exceed one-half (1/2) of the yield stress or one-fourth (1/4) of the ultimate stress.

TM-1.11 STAY RING AND STAY VANE

The stay ring shall be of welded plate steel or cast welded construction, heat treated before final machining to relieve locked-up casting or fabrication stresses. It shall consist of two rings, rigidly held together by stay vanes, which guide the water to the guide vanes. The stay vanes shall be designed and shaped to direct the water flow with a minimum head loss and to eliminate vibration.

Machined flanges shall be provided for bolted connections between the stay ring and the head cover, between the stay ring and the bottom ring or discharge ring.

The surfaces of the stay ring and weld joints in contact with water shall be ground to a smooth finish of 12.5 µm. Welds in stay ring shall be inspected by dye-penetration test / ultrasonic test wherever necessary.

TM-1.12 GUIDE VANE RING

All guide vanes and operating mechanism bearings shall be of a self-lubricated bearing of a type successfully used for the respective application intended, such as “Thordon”, “Fiberglide” or accepted equivalent.

A renewable stainless steel seal ring, accurately machined to form a water seal with the runner crown and shaped to reduce leakage

In the case of a Francis turbine, A wearing surface of stainless steel overlay or removable stainless steel plates shall be provided by the contractor.

TM-1.13 DISCHARGE RING (IF APPLICABLE)

The discharge ring shall be of cast steel or welded plate steel. If the discharge ring is of welded plate steel, all butt welds shall be fully penetrated, and all welds shall be stress relieved before machining. It shall be of heavy section and adequately ribbed externally to secure proper anchorage to the concrete and to prevent distortion.

The discharge ring shall be provided with flanges on both ends for bolting to the bottom ring or stay ring. The end shall have either a flange for bolted connection or an extension for welded

connection to the draft tube liner. Adjusting jacks with steel bearing plates shall also be furnished to facilitate leveling during installation.

TM-1.14 DRAFT TUBE

The draft tube shall be made of welded plate steel and shall be adequately ribbed and stiffened to prevent distortion. The first section of the draft tube close to the runner outlet shall be faced with or constructed from 13% chromium 4% nickel stainless steel. The straight draft tube shall be partially embedded in the concrete slab.

A 2 mm increase in shell plate thickness is required as a corrosion allowance.

A draft tube pressure and vacuum gauge connection as well as flange pipe connection shall also be furnished in the liner.

The liner shall be completely assembled and match-marked in the shop with all ribs accurately fitted. The liner shall be shipped in as few pieces in view of transport limitation.

The Contractor shall supply all necessary stiffeners, anchors, jacks, turn buckle etc. for proper site assembly & alignment, during erection.

TM-1.15 TURBINE GUIDE BEARING (IF APPLICABLE)

a. The bearing shall be of:

1. Pad type or sleeve type having babbitt metal lining. Oil grease lubricated or self-lubrication or forced lubrication type.
2. Anti friction ball/roller bearing, oil or environment-friendly grease lubricated type.

These bearings shall be guaranteed for continuous working for one hundred thousand (100,000) hours and shall be of proven design and performance.

Bearings shall be adequately insulated to prevent any harmful circulating currents. The thrust bearing shall be suitable to take axial thrust in both directions. The bearing shall be designed to withstand any damage, in case the machine is operated on runaway speed for a period of 5 minutes.

The oil used shall be the same as used for turbine governing system and generator bearing.

The temperature of the bearing metal shall not exceed the provision in Table 1 when the temperature of cooling water is 30°C.

Table 1 Allowable temperature rise values for the hydro turbine generator bearings

Type of the bearing	Maximum allowable for alarm °C	Maximum allowable for trip °C
Babbitt bearing bush of thrust bearing	75	80

Babbitt bearing bush of guide bearing	70	75
Rolling bearing	95	100

b. Force Lubrication Type Bearing (if required)

If required, the system shall be of the proven manufacturer's standard design.

c. Bearing Temperature Indication

Dial type thermometer complete with one (1) independent settable contact making for alarm and trip temperatures and hand resetting of maximum temperature indicator shall be provided for each bearing and shall measure bearing shell or pad temperatures as close to the lining to journal or thrust ring interface as practicable.

d. Lubrication Oil Cooling System (if applicable)

If required, the system shall be of the proven manufacturer's standard design.

TM-1.16 SHAFT SEAL

A shaft seal shall be provided to prevent the leakage of water along the shaft base on the Contractor design.

(If Required) The shaft seal shall be arranged for water lubrication. Two (2) or more connections for clean water shall be provided, evenly spaced on the periphery to admit a supply of clean water at a pressure sufficient to exclude foreign matter from the seal. Any leakage water from the seal shall be removed by drains.

The Contractor shall provide the necessary water filtration equipment, piping and valves including pressure reducing valves (if required). Filtration shall remove particles larger than 100 µm and shall be provided with automatic backwash equipment with controls and shall be sized to ensure continuous maintenance-free water supply to the shaft seal. Piping and valve shall have sufficient size for normal operation and flushing operation.

The shaft seal housing shall be made of cast steel. The shaft protecting sleeve shall be made of stainless steel.

A shaft water seal flow transducer 4-20 mA with direct reading instrument shall be provided in the water supply piping to the seal. A 100 mm duplex pressure gauge shall be provided for indicating the pressure beneath the seal and in the supply line.

TM-1.17 GUIDE VANE AND OPERATING MECHANISM

The turbine shall be equipped with one (1) set of guide vanes. These guide vanes shall be either cast or fabricated construction of stainless steel or iron. The stainless steel shall comply with ASTM 743 Grade CA-6 NM, EN 1.4313 (X3CrNiMo13-4), GX4CrNi13-4. The cast iron shall comply with ASTM A536 Grade 70-50-05, EN-GJS-500-7. The stems shall be cast or fabricated construction of stainless steel. The guide vanes shall be uniform in shape and their cross-sections shall be such as to direct properly and accelerate gradually the water entering

the runner with a minimum of friction and hydraulic disturbance. The guide vanes shall have a self-closing tendency over the greater part of their operating range including the fully closed position.

All guide vanes and operating mechanism bearings shall be of a self-lubricated bearing of a type successfully used for the respective application intended, such as “Thordon”, “Fiberglide” or accepted equivalent.

Guide vanes, stems, links and operating rings shall be designed to produce a minimum of lost motion and friction. The guide vanes shall be connected through couplings, links and levers to the guide vane regulating.

A suitable shear pin, spring load, friction device or breaking link shall be provided between each guide vane stem and the regulating ring and shall be strong enough to withstand the maximum normal operating forces, but which will break or release in the event of excessive forces acting in either the opening or closing direction and will protect the rest of the mechanism from damage in case one or more of the guide vanes become blocked.

Stops shall be provided to limit the angle of movement of the guide vane stem levers in case of breaking of the shear pin or link so that interference of the loose guide vane with operation of the other guide vanes will be prevented.

A manually adjustable stop shall be incorporated, with which the motion of each guide vane in the opening direction can be positively limited.

An alarm feature shall be provided so that a circuit shall be broken in the event that any one of the shear pins fails. The Contractor shall be provided at each shear pin to facilitate repair of the alarm circuit in the event of failure. The alarm circuit shall be protected from damage by flexible or rigid conduit where appropriate. It shall be terminated at a junction box on the wall of the turbine pit for connection to external circuits. Each replacement shear pin included in spare parts inventory shall be wired ready to connect into the alarm circuit.

TM-1.18 TURBINE REGULATION

TM-1.18.1 Guide Vane Servomotor

The turbine shall be provided with oil pressure operated double acting hydraulic servomotor and/or with counter-weight having a capacity sufficient to supply the maximum force necessary to operate and hold closed the guide vanes, under maximum operating head, at the minimum oil pressure. The servomotor shall be designed for the maximum allowable working pressure of the governor system. The servomotor shall be capable of moving the guide vanes from a complete close position to a fully open position in one stroke and vice versa.

The servomotor cylinder shall be made of cast steel or welded steel plate. Welds shall be fully penetrated and stress relieved.

The servomotor piston rod shall be provided with self-lubricated bushing. The piston rod shall be arranged for adjustment of stroke. Cushioning shall be provided over the last 10% of stroke in each direction.

Chevron type packing shall be used to prevent oil leakage from the cylinder past the piston rod. The piston connecting rod shall be of forged steel of uniform diameter. Each piston shall be

fitted with not less than three piston rings, suitably shaped to give close contact and uniform pressure on the cylinder walls. The servomotor cylinder shall be provided with flanges for connecting oil piping. An air vent and a drain cock shall be provided on the servomotor for air release and oil draining. Outlet of each shall be provided with a plug.

A manual locking device of a simple construction to permit locking the guide vanes in either the open or close position and capable of withstanding safely the full operating force of the servomotor shall be provided at the servomotor. The device shall be such that it can be easily engaged and disengaged by one man. Electrical contact switches suitable for indication shall be provided to indicate guide vane lock in the full open and full close positions. An additional contact for unit starts interlock shall be provided. All contacts shall be wired to terminal blocks in the turbine terminal box.

Bypass connections, equipped with orifices and/or adjustable needle valves, with a secure means of locking the adjustment, shall be provided on the servomotor to retard the rate of closure of the guide vanes slightly below speed-no-load to the full close position. The bypass connection shall be fitted with check valve to prevent sluggish movement on opening the guide vanes from the full close position.

A suitable pointer and scale, graduated in tenths with subdivisions, shall be provided at the servomotor to indicate the percent stroke of the servomotor and guide vane angle in degrees from the close position. The scale shall be calibrated in the field and marked 'closed' at one end of the scale and 'opened' at the other end.

The servomotor must be fitted with a stroke limiter which is capable of manual adjustment. Means for positively locking the adjustment must be provided.

The servomotor shall be pressure tested according to TG-18 Inspection and Test: Electrical/Mechanical.

TM-1.18.2 Runner Blade Servomotor (if applicable)

With the minimum governor operating oil pressure, specified in the "Guaranteed Characteristics", the servomotors shall have a combined capacity sufficient to supply the maximum necessary force for moving the turbine guide vanes and the runner blades (if applicable) under all conditions of load and head, including allowance for water hammer. The velocity of oil in the pipe ports of the servomotor shall not exceed four (4) meters per second.

TM-1.19 TURBINE SHAFT (IF APPLICABLE)

The turbine shaft shall be made of forged carbon steel, properly heat treated in accordance with TG-7 Materials. It shall be provided with integrally forged coupling flanges for connecting to the generator shaft and to the runner. It shall be of ample size to operate at any speed up to the full runaway speed without detrimental vibration or distortion and to operate at maximum output without exceeding normal design stress.

The turbine shaft shall be accurately machined all over and polished where exposed to view from the guide bearing journal, up to and including the coupling and the coupling guard to a surface finish of 3.2 microns. The guide bearing journal shall be polished to give a finish not to exceed 0.4 microns R_a (R_a is roughness average as defined in ANSI/ASME B46.1).

TM-1.20 LUBRICATING OIL (IF APPLICABLE)

The oil for filling the turbine guide bearing shall be as specified in TG-17 Lubricants. Oil shall be supplied by the Contractor.

TM-1.21 TURBINE TERMINAL BOX

The details of turbine terminal box are specified in TG-10 Electrical Equipment.

TM-1.22 TURBINE ELECTRICAL AUXILIARIES

The Contractor shall supply all the necessary switches, contactors, magnetic starters and relays with the turbine electrical auxiliaries according to this subsection and other sections of the specifications.

All electrical items supplied by the Contractor shall comply with the appropriate section of the ANSI, NEMA and EEMAC standards. They shall be arranged in a manner approved by EGAT. The Contractor shall provide and supervise to install terminal boxes in locations to be approved by EGAT and shall provide all wiring and conduit from his electrical components to these terminal boxes.

The Contractor shall supply all electrical wiring and conduit within the turbine pit including wiring for pressure switches, flow switches, temperature relays, and thermometer alarms. All wiring shall be terminated at terminal blocks in the turbine terminal box located in the turbine pit. All wiring shall be stranded wire and insulated with 600 V oil proof insulation.

Refer also in TG-10 Electrical Equipment for other electrical requirements.

TM-1.23 PAINTING

The Contractor shall be responsible for the turbine and shall strictly comply with the specified Clause TG-14 Painting.

The finish color of the turbine shall be painted RAL 1014 (Ivory) in accordance with TG-14 Painting.

TM-1.24 SHOP ASSEMBLY

The turbine shall be assembled or sub-assembled in the Contractor's shop to prove the design, construction and machining for proper fits and clearances. Parts shall be properly match-marked, identified and doweled to ensure correct assembly and alignment in the field, except that where necessary, suitable dowels shall be furnished for insertion after field assembly and drilling.

The shop assembly shall include the runner, spiral case, head cover, stay ring, guide vane operating mechanism, discharge ring and draft tube.

TM-1.24.1 Regulating Mechanism

The guide vanes shall be operated through their full movement of full servomotor stroke, as may be required, to demonstrate that the guide vanes and regulating mechanism function properly without interference or binding.

TM-1.24.2 Shop Measurement

Controlling dimensions and small clearances of the assembly shall be measured and recorded on illustrated shop inspection forms, showing the design drawing dimensions and the actual measured dimensions as well as allowable tolerance. Copies of shop inspection forms in the English language shall be submitted to the EGAT for review prior to the first shop assembly inspection. Clearances between the guide vane and operating mechanism, and clearances along the line of contact of closed guide vanes (without squeeze) shall be measured and recorded. Guide vane openings shall be measured at the top, bottom and mid-height and recorded at fully open position, if feasible.

TM-1.24.3 Hydraulic Pressure Withstand Test

As per EGAT requirement, the spiral case, hydraulic servomotor cylinders, PRV, heat exchangers, pressure tank/air receiver and cooling water strainers or filters shall be hydrostatically tested conforming ASME Boiler and Pressure Vessel Code, Section VIII, Division I.

TM-1.24.4 Guide vanes Breaking Elements/Protection Devices Tests (if applicable)

To demonstrate that the guide vanes breaking elements protection devices will operate appropriately at the design load, a test shall be performed in the shop using equipment to simulate the actual operating conditions. Not less than two (2) elements shall be tested per unit. Descriptions of the test rig and the test results shall be submitted to the EGAT prior to such tests, and the test results shall be submitted to the EGAT after each test is completed.

TM-1.24.5 Witnessing of Shop Assembly and Test

The shop assembly tests shall be witnessed by EGAT.

The Contractor shall carry out tests and measurements to demonstrate to EGAT that the equipment has been constructed according to the approved drawings and the provisions of the Technical Specifications.

TM-1.25 FIELD TEST

TM-1.25.1 General

Turbine field tests after erection shall be done to determine whether the equipment meets these technical specifications and the “Guaranteed Characteristics” of the Contract. The Contractor shall carry out tests and testing instrument. Testing instrument shall remain the Contractor’s property unless otherwise specified.

Final adjustments and tests before commissioning on completion of erection dry tests shall be performed. They include:

- Pressure test of oil, water and compressed air piping shall comply with ASME B31.1
- Manual rotation of the rotation assembly and inspection of the clearances
- Operating check of safety and control devices and alarms

- Operation of guide vanes and adjustment of closing time
- Operation of PRV (if turbine unit design with PRV)

TM-1.25.2 Commissioning and Acceptance Test

Commissioning and acceptance tests shall include. The Contractor shall carry out tests and testing instrument. Testing instrument shall remain the Contractor's property unless otherwise specified.

a. First Run (Up to speed-no-load operation and connection to the grid.)

During this test shaft run-out shall be measured at the turbine and generator bearings.

b. Heat Run Test

The unit shall be run at speed-no-load for an adequate time that temperatures in the bearings, the stator, and the various cooling and lubrication systems stabilize. The speed-no-load test shall be run for a minimum of two (2) hours.

After the unit stabilizes at speed-no-load the unit loading shall be increased at suitable increments as agreed between the Contractor and EGAT. Minimum increments shall be at 25%, 50%, 75% and at rated load and maximum efficiency.

After the unit is run at rated load and maximum efficiency, the unit shall be operated at 100% gate (full flow) conditions for an adequate time.

c. Output Test

The turbine shall be subject to a full-scale output test to check that turbine output according to TM-1.5.1 Turbine Output is met.

The output test shall be carried out at net heads as close as possible to the net head for which is specified in prototype hill chart. Adjustments will be made on the basis of the prototype hill chart to take into account the difference between effective net head and specified net head.

The net head shall be measured according to IEC Code Publication 62006 "Hydraulic Machines – Acceptance Tests of Small Hydroelectric Installations". The Contractor shall provide for the unit the pressure taps and the piping required as per IEC Code. The instrumentation for the test shall be provided by the Contractor, but will remain his property.

The turbine power shall be determined from the power at generator terminals and from the generator efficiency.

The turbine shall also be tested to check the maximum continuous output at generator terminals.

d. Maximum Output Test

The turbine shall be subject to the maximum continuous generator output test. This test shall be carried and for 8 hours. The Contractor shall carry out tests and testing instrument. Testing instrument shall remain the Contractor's property unless otherwise specified.

e. Load Rejection

Load rejection shall be carried out from 25%, 50%, 75%, and 100% of the full load. The overspeed at each load rejection shall be measured.

f. Performance Test

As a part of the tests on completion an index test for the turbine shall be performed. The tests will be made to confirm the run of the turbine efficiency curve considering the recommendations made during the model tests.

EGAT and the Contractor shall cooperate to find a mutually satisfactory date for testing when sufficient water is available to demonstrate the efficiency and the output of the turbine.

The Contractor shall furnish to EGAT two copies of the records and tabulated results of the index tests, certified by the test Engineer. Such records shall include relative efficiency, hydraulic head, output and speed for the turbine as determined by the tests.

The Contractor shall furnish all instruments, apparatus and equipment necessary to make the above tests, which will remain his property, together with a trained and experienced test engineer.

The turbine capacity shall be determined from electrical measurements of generator output and the guaranteed efficiencies of the speed increaser (if applicable).

TM-1.26 REQUIRED SPARE PARTS

The Contractor shall supply the following commissioning required parts.

- | | |
|--|-----------------------|
| 1) Seal, packing, piston rings, etc for guide vane servomotor | one (1) complete set |
| 2) Seal, packing, piston rings, etc for PRV (If applicable) | one (1) complete set |
| 3) Bushings for 2 guide vanes | two (2) complete sets |
| 4) Safety device (Shear pin, friction, spring, etc) for guide vane | one (1) complete set |
| 5) Packing and seal | one (1) complete set |

One complete set of required parts described above is defined as the total number of the parts required for one (1) unit of the equipment specified in this Chapter. Each type of commissioning required parts stands for the different parts in sizes, pressure or current ratings, functions, etc.

End of Chapter

TM-2 SPEED GOVERNOR

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TM-2 SPEED GOVERNOR

TM-2.1 GENERAL

This section specified the detailed requirements of the governor with accessories. The Contractor shall be fully responsible for the design, manufacturing, shop test, deliver, installation and field test the equipment and instruments for complete system function.

TM-2.2 TYPE AND DESCRIPTION

The governor shall be of digital type with PID structure and modular design having a record of satisfactory and reliable service and at least as specified herein. Independent adjustable stabilizing control circuits shall be included in the control system to allow the unit to operate with an adequate margin of stability under all steady state and transient load conditions. The complete governing system shall operate with a high degree of reliability, freedom of drift and negligible dead-band.

The governor shall consist of a programmable logic controller (PLC), single-channel speed sensing system with included check to plausibility, self-supervision, main distributing valves, hydraulic control valves, governor oil system, speed signal device (SSD) for energizing the speed sensing circuit, feed-back transmitter, remote input/output circuits, instrument and protective devices for a complete operating unit. If PRV is applicable, the main distributing valve shall be designed to commonly control the governor and PRV with fulfilled function when unit operates under normal operation and emergency operation. The operating Nitrogen/oil pressure shall be determined by the Contractor in accordance with his usual practice subject to the approval of EGAT.

Integrated Unit Control

The turbine governing control shall be provided within an integrated unit controller as specified in Clause TE-5.2.2.2. The controller shall perform all or any combination of unit sequence, turbine governing and excitation control including generator synchronizing, water level and speed monitoring with the proven software.

The system shall be so arranged that manual and automatic control facilities are available both remotely in unit control panel and through the supervisory control and monitoring system specified under Clause TE-5 of this Technical Specifications: The governor shall afford smooth changeover from manual to automatic and vice versa, under all operating conditions, without disturbing the operation of the turbine. The speed/load adjustment shall be operated either at the unit control panel or at operator control station (OCS) or by the automatic synchronizing equipment.

If a control system separated from the integrated unit control is provided, the contractor shall include details of the proposed control concept and design with their bid.

TM-2.3 CAPACITY AND OPERATING CONDITION

TM-2.3.1 Capacity

The governor system shall have sufficient capacity when deriving energy from the accumulator tank only to operate the turbine guide vanes, runner blades (if applicable), brake (if applicable), PRV (if applicable), Inlet valve (if applicable), etc. through complete opening and closing stroke at any head up to maximum head when the oil pressure is at its lowest value. The governor shall have sufficient capacity, without overloading, to hold the adjustments of the guide vanes at all openings.

TM-2.3.2 Operating Conditions and Requirements

The unit will be connected to the 22 kV network of the Provincial Electricity Authority (PEA). For normal operation it is not required the governor to make a frequency regulation and the governor shall be equipped with a circuit manually adjusted which shall energize the governor action in a frequency range between 49.5 Hz and 50.5 Hz.

The design closing time of the guide vanes shall be designed so that the speed rise of the turbine and the maximum pressure rise in the penstock shall not exceed the value defined in the guaranteed characteristics.

The governor shall be capable of controlling with stability, the speed of the turbine when operated at rated speed and no-load, or when operating at rated speed at all power outputs, including maximum output of the turbine.

TM-2.4 GOVERNOR CONTROL

The electrical components of the electro-hydraulic governor shall include the following:

- a) Speed signal device (SSD) mounted on the generator shaft and directly driven by it and electrically linked to the governor.
- b) The governor shall compare the speed settings with the incoming speed signals from the speed sensing device.
- c) The digital governor shall produce a DC output signal to operate the electro-hydraulic solenoid valves.
- d) Power supply supplied from powerhouse is 48 V DC system as specified in Clause TG-5, Control and Auxiliary Power Supplies.
- e) All required feedback circuits for stabilization.
- f) The speed regulation is provided for synchronizing and full power rejection (quick shut down).
- g) Electro-hydraulic transducers to transfer the electrical signal to hydraulic for the regulation of guide vanes. (if applicable)

The governor shall be equipped with a self diagnostic system in order to give signals for alarms and/or trips and localize the point of failure if any. All adjustments including those affecting unit stability shall be readily accessible while the governor is regulating.

TM-2.5 WIRING

Electrical wiring within the unit control panel shall be concealed and arranged for external connections. The panel shall permit cable or conduit entrance through the bottom of the panel as required. All wiring shall be color coded as approved by the EGAT and insulated with 600 volts oil-proof insulation; it shall be formed into flat or rectangular groups and properly supported. All connections shall be made at terminal studs or terminal blocks. Terminal blocks shall be rated not less than 600 volts. At least 10 percent extra terminals shall be provided in each group of terminal blocks.

TM-2.6 INSTRUMENT AND CONTROL DEVICE

The contractor shall provide the instrument and control device as follows:

- a) Emergency shutdown push button

TM-2.7 FUNCTION

The equipment and instrument shall send a signal to the unit control panel.

TM-2.8 DISPLAY CONTROL AND MONITORING

The unit control panel shall have a capable of monitoring and displaying the parameters of indicators as the following;

- a) Oil pressure / Oil temperature / Oil level
- b) Guide vane/runner blade (if applicable) position
- c) Upstream and downstream water level
- d) Bearing temperature
- e) Annunciation system

TM-2.9 GOVERNOR OIL SYSTEM

TM-2.9.1 General

The governor oil system shall be designed in a compact unit with built-in accumulator, and have capacity as required for controlling the turbine guide vane, runner blade(if applicable), brake (if applicable), PRV(if applicable), Inlet valve(if applicable), etc.

The governor oil system unit shall be completely assembled in one (1) set, testing at manufacturer work shop and ready to installation.

The governor oil system unit consists of the following parts below:

TM-2.9.2 Main oil pump

One (1) main motor driven oil pump, having a capacity per minute of the total oil volume of the turbine guide vane, runner blade (if applicable), brake (if applicable), PRV (if applicable), Inlet valve (if applicable), etc. conforming to IEC 61362, shall be provided. One (1) hand-pump shall be provided.

The motor shall be suitable for operation on 400 V, three phase, 50 Hz power supply and shall be squirrel cage, low starting current, induction type, designed for full voltage starting and conforming to IEC Standards IP 54 Class F insulation. The magnetic starter contactor with disconnecting switch and overload protection for the motor shall be provided

The system shall be provided with adjustable unloader valve, proportional valve/servo valve, pilot control valve, safety relief valve, check valve, temperature relay and pressure switches.

An adjustable temperature switch with two electrically separate contacts suitable for operation at 48 V DC shall be located in the pump suction side for high oil temperature alarm.

A suitable oil filter/strainer shall be provided.

TM-2.9.3 Oil Sump Tank

The oil sump tank shall be provided with a capacity of not less than 110 % of the total quantity of oil in the entire governor. The tank shall be completed with instrument and protective device, i.e. temperature and water flow detectors with alarm contact for cooling oil lubrication, oil-water detector, filter, oil level indicator, sight glass, pressure gauge, supply line for filling the tank and a drain connection for draining the tank. All filters shall be readily removable for cleaning.

An adequate manhole with a suitable oil resistant gasket for access to interior of the tank shall be provided.

The maximum oil temperature shall not exceed 65 °C., if applicable, oil cooler shall be provided.

TM-2.9.4 Piping and Valve

The Contractor shall supply all interconnecting piping and valves between main oil pumps, oil sump tank and accumulator tank as well as connecting between a new governor oil system and new guide vane servomotors including the oil drain lines to sump.

The oil supply piping shall be fitted with an oil outlet stop valve to enable the governor to be isolated from the nitrogen or oil system.

TM-2.9.5 Governor Oil

The Contractor shall provide all oil requirements for the governor hydraulic system plus an additional ten (10) percent.

The governor oil shall be of a type available in Thailand market.

TM-2.9.6 Nitrogen/oil Accumulator System

The Nitrogen/oil accumulator system shall be provided instead. The system shall be a proven manufacturer's standard design having capacity and reliability as required by the governor operating condition as specified in IEC61362 and TM-2.3. Details of the system include PI diagram, technical description & data, catalog, etc. shall be proposed by Contractor in his bid proposal.

TM-2.10 WRENCH AND TOOL

The Contractor shall furnish set of standard special tools to be required for assembly and maintenance. The wrenches and tools shall be unused and put in a tool box.

TM-2.11 PAINTING

The Contractor shall be responsible for the governor and shall strictly comply with the specified Clause TG-14 Painting.

The finish color of the governor shall be painted RAL 1014 (Ivory) in accordance with TG-14 Painting.

TM-2.12 INSPECTION AND TEST**TM-2.12.1 General**

All equipment and material shall be subject to inspection and testing as specified in TG-18, Inspection and Test-Electrical/Mechanical.

The Contractor shall furnish certified copies of all test results. The results of each test shall be recorded in the form of test certificates or reports as specified in Clause SC-4 Documents to be prepared by the Contractor.

Type tests may be offered by the Contractor as specified in TG-18 Inspection and Test-Electrical/Mechanical, provided the Contractor gives evidence to the EGAT as to the similarity of the equipment tested and the Contract equipment.

TM-2.12.2 Shop Tests

The equipment shall be subjected to shop tests and in accordance with the latest issue of the applicable standards.

In addition, the Contractor shall perform the following shop tests:

a) Material Tests

Material tests shall be as specified in TG-18 Inspection and Test-Electrical/Mechanical.

b) Hydrostatic Tests

Hydrostatic tests shall be as specified in TG-18 Inspection and Test-Electrical/Mechanical.

c) Shop Tests

Shop tests shall be as specified in TG-18 Inspection and Test-Electrical/Mechanical.

The equipment shall be functionally tested in so far as practicable in the Contractor's plant, to test operation of all circuits and devices, and to optimize performance. Bill of material or parts list shall also be checked.

TM-2.12.3 Field Tests

The Contractor shall carry out field inspections and tests and in accordance with the latest issue of the applicable standards.

Complete tests shall be performed on site under the supervision of the Contractor, to check the sequence of operation and to optimize performance of each item of equipment during all normal and abnormal operating conditions mentioned specifically or implied in this specification. The tests shall prove that all specified requirements have been met.

Other tests on governing equipment are part of TM-1.25 Field test

TM-2.13 REQUIRED SPARE PARTS

All required parts furnished by the Contractor shall be interchangeable with the corresponding parts of the governor furnished under these Technical Specifications.

At least the following spare required parts for the governor and governor auxiliary equipment shall be furnished:

- | | | |
|----|----------------|----------------------|
| 1) | Sensing device | one (1) of each type |
| 2) | Limit switch | one (1) of each type |
| 3) | Oil filter | one (1) of each type |

One complete set of required parts described above is defined as the total number of the parts required for one unit of the equipment specified in this Chapter. Each type of required parts stands for the different parts in sizes, pressure or current ratings, functions, etc.

End of Chapter

TM-3 SPEED INCREASER (IF APPLICABLE)

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TM-3 SPEED INCREASER (IF APPLICABLE)

TM-3.1 GENERAL

This Section specifies the detailed requirements for the design, manufacture and testing of speed increasers, with associated equipment, to be furnished in accordance with these Technical Specifications.

TM-3.2 GENERAL DESCRIPTION

The speed increaser has to be designed to fit the turbines and generator requirements. Drive will be suitable to interface between the main hydro-turbine driver and driven generator.

The envelope design will be such that the drive will cleanly interface with the supporting foundation, turbine and generator shafting and support equipment within the turbine pit assembly.

The primary function of the arrangement is to accept the dynamic torque and thrust loading from the turbine operation and transmit the required torque to the generator

The minimum efficiency of the unit (Turbine + Speed Increaser + Generator) at the rated net head and rated flow shall not be less than 87.4%.

TM-3.3 CONFIGURATION DESCRIPTION

The gearbox speed increaser is calculated in according to AFNOR NF E 23 015, DIN 3990/3991 or ANSI/AGMA 6113-B16.

The low speed shaft is made with a bore and is directly attached to the turbine shaft with a flange on the downstream side. The connection from the high-speed shaft to the generator shaft is done by means of and the coupling.

For ease of maintenance, the gear drive will incorporate design features that will permit removal from the installation independent of the turbine shaft and generator.

The gear drive will be equipped in accordance with the specifications and include the necessary provisions for temperature measurement devices to monitor operating parameters.

The belt and pulley speed increaser is calculated in accordance to ISO and DIN standards.

TM-3.4 COMPONENT DESCRIPTION

TM-3.4.1 Gear Accuracy

The gears will be precision hobbled, carburized and precision surface to DIN Quality level 6 or corresponding to an AGMA Quality 11/12.

TM-3.4.2 Housing

The gear case housing shall be designed and constructed of welded steel, suitably ribbed and reinforced to withstand all normal loads imposed during operation and accurately machined and proven practice to ensure maximum strength and rigidity.

The housing shall have its strength concentrated at the point of attachment of the fixed member of the gear drive. The construction shall ensure that the torque reaction is directly transmitted to the foundation.

Inspection openings shall be provided and arranged in such a way as to permit internal gearbox inspection,

All housing sections shall be suitably stress relieved after welding, cleaned of mill scale and weld spatter, and sealed with an oil compatible sealer to prevent internal rusting.

TM-3.4.3 Bearing

The bearings shall be anti-friction type bearings.

An integral thrust bearing arrangement shall be incorporated into the design in order to accept turbine thrust. The thrust bearing arrangement shall be double acting in order to accept thrust reversals.

The thrust bearing shall be capable of continuous operation under maximum load condition at any steady state speed up to steady state runaway speed and at the maximum transient over speed without limitation on the number of occurrences.

The bearing B-life time shall be at least 100,000 hours.

TM-3.4.4 Servicing

The design shall allow for complete removal of the speed increaser (as an assembly) from the turbine shaft and generator shaft connections. This entire assembly can then be fitted through the access opening in the powerhouse.

TM-3.4.5 Lubrication System

The Contractor shall design and manufacture the lubrication system suitably sized to meet the requirements of the drive under all operating conditions.

The arrangement of this system will be such as required to provide the necessary pre-lubrication, full load operation, and coast down lube oil requirements.

The main lubrication oil pump shall be direct driven by the high speed shaft to support all oil flow needs during operation and the electrical driven pump is used during start-up and stopping of the unit- if necessary.

The first oil filling shall be done with oil proposed by the manufacturer and approved by the Engineer.

The first oil check shall be done after trial operation, shall be repeated according to the maintenance instructions and it should be changed upon necessity of the quality.

TM-3.4.6 Instrument

The entire lubrication system shall be designed for a maximum ambient temperature of 40°C. Moreover, the following main components are part of the lubrication system:

- a) One (1) Oil filter with electric contamination indicator (is necessary in case the Contractor propose a water cooler)
- b) One (1) Flow control valve with contacts installed in the main pressure line
- c) One (1) Pressure switch installed in the main pressure line
- d) One (1) Pressure gauge in the oil circuit pipes
- e) One (1) Oil level gauge with low and high level contacts and an oil level sight device
- f) One (1) Temperature-controlled valve
- g) One (1) Thermometer with closing contacts to regulate cooler

TM-3.5 SHOP TEST

The speed increaser shall be given complete functional test at no load and other test according to the applicable standard with corresponding reports.

The efficiencies have to be proved with calculations according to the AFNOR, DIN, ISO or ANSI/AGMA Standards with the corresponding tolerances.

TM-3.6 FIELD TEST

Field test after erection shall be performed to determine whether the equipment meet these Technical Specifications and the "Guaranteed Characteristics" of the Contract.

End of Chapter

TM-4 HYDRO-MECHANICAL EQUIPMENT

EQUIPMENT WORKS

MECHANICAL EQUIPMENT - TECHNICAL SPECIFICATIONS

TM-4 HYDRO-MECHANICAL EQUIPMENT

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TM-4 HYDRO-MECHANICAL EQUIPMENT

TM-4.1 MAIN VALVE

TM-4.1.1 General

This section specified the detailed requirements of main valve complete with manual operating mechanism.

TM-4.1.2 Type and Description

The main valve shall be of the biplane butterfly type with horizontal shafts manual operating mechanism or high pressure slide gate with vertical shafts manual operating mechanism. The minimum acceptable size for the butterfly valve is 1,600 mm. The valve body and disc shall be so proportioned and sized that, when fully open, there will be minimum obstruction to flow of water. The design of the valve body and transition section shall be such as to adequately resist the hydraulic forces acting directly on the body and transition section, and those resulting from the thrust of the disc when in a closed position. The body shall be properly ribbed circumferentially to ensure sufficient rigidity to minimize deformation. A flexible coupling shall be provided between the downstream flange of the valve and the penstock. The valve shall be a standard, manufactured type to ensure interchangeability of parts.

Closing and opening of the valve shall be made manually by hand force of not more than 10 kg.

Valve assembly shall include but not necessarily be limited to

- a) One (1) valve body assembly, including valve body, disc, shaft together with greaseless bearings, adjustable seals and appurtenances
- b) One (1) manual operating mechanism, including gears and handwheel, and a mechanical locking device.
- c) Two (2) sets of pressures gauges and guard valve.
- d) One (1) bypass assembly, with piping, manually operated valve and guard valve.
- e) One (1) set of transition sections, if applicable
- f) One (1) flexible coupling between downstream flange of the main valve and the penstock.
- g) Two (2) drain valves at upstream and downstream flange of the main valve.
- h) Additional features and accessories as specified or required, including anchor bolts, nuts, washers, suitable lifting devices and support beams.

TM-4.1.3 Design Criteria

The valve shall normally be closed or opened under equalizing pressure across the disc. However, in case of the main valve and penstock failure, the valve shall be able to shut off water under all operating conditions.

The valve shall normally be opened only after a pressure equalization across the disc.

The valve shall be designed for the following conditions.

- | | | |
|---|------------------------------|--|
| - | Maximum design pressure | Not be less than 1.1 times of maximum pressure in penstock |
| - | Maximum pressure of penstock | To meet the requirement in TM-1.4 |

All parts subject to the maximum hydraulic pressure, shall be in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, Division 1. The allowable stresses for non-pressurized steel parts shall not exceed the values of the AISC Specifications for the design, fabrication and installation of structural steel for buildings.

A 2 mm. corrosion allowance shall be added for the transition sections and the valve body and disc.

TM-4.1.4 Description of Components

TM-4.1.4.1 Valve Body

The valve body shall be of normalized cast steel or stress relieved welded steel, and shall have a corrosion-resistant sealing seat of a type to receive the rubber seal. The valve body shall be machine finished where required for matching parts, and drilled to receive the shaft bearings. The body shall be flanged on both ends, and the flanges shall be faced, shop-drilled and spot-faces. The drilling shall match the drilling of the companion flanges for the transition sections.

Pads shall be provided on the valve body for transmitting the vertical load to the concrete foundation. Suitable beams and anchor plates and bolts for securing the valve in position shall be provided. The body and transition sections shall be so arranged that no weight or vertical thrust from the valve, transition section or contained water is applied to the spiral case. The support pads shall be of a type to permit adequate movement in the upstream and downstream directions for the valve opening or closure.

TM-4.1.4.2 Valve Disc, Shaft and Seal

The disc shall be of the biplane type, made of normalized cast steel or stress relieved welded steel, and shall be so designed and constructed as to produce a minimum of hydraulic loss. The disc shall be of streamline section to minimize local eddy currents and sudden velocity changes. All surfaces of the disc in contact with water shall be smooth and free from hollows, depressions, cracks or projections that might cause pitting due to cavitation.

The disc and shaft shall be designed to adequately resist the forces acting directly on the disc when in closed position, with utmost rigidity to ensure a minimum of deformation. The disc and shaft may be integrally cast. If not integrally cast, the disc shall be bored and key-seated to receive the shaft, which shall be held in position by keys and pins. The valve disc shall be designed and machined to accommodate the valve seal. The seal shall be of rubber or synthetic polymer. The seal retainers and seal fasteners shall be of suitable corrosion-resisting steel. The seals shall be designed and constructed of such materials that they will provide maximum tightness, minimum maintenance and convenient adjustment and replacement. The adjustment feature may be accomplished either in the seal retaining elements or in the seal seating element from the downstream side of the valve. The disc shall be of sufficiently rigid construction and

the sealing surfaces shall be so designed that there shall be no jamming when water is drained from the penstock after closure under full head.

TM-4.1.4.3 Valve Bearing

The bearings shall be of a greaseless type. The bearing design shall be such that no water leakage.

TM-4.1.4.4 Bypass Assembly

The bypass assembly shall include one (1) bypass valve operating with manual operating mechanism, one (1) manual guard valve, piping flanges, fittings, bolts and gaskets, sensors and instruments. The manual guard valve shall be gate type and located on the upstream side of the bypass valve.

All pipes, valves and fittings shall be at least PN6.

TM-4.1.4.5 Flexible Coupling

The flexible couplings shall be gasketed, sleeve type, with diameter to properly fit the pipe. The coupling shall consist of one (1) steel middle ring, of thickness and length as required, two (2) steel followers, two (2) rubber-compounded, wedge-section gaskets and sufficient number of bolts to properly compress the gaskets.

The middle ring shall be of mill-contoured section with longitudinal joints. The finished ring shall be a true circular section, free from irregularities, flat spots or surface defects. The followers shall be of mill-contoured section. They shall be of such strength to accommodate the number of bolts necessary to obtain adequate gasket pressure without excessive rolling. The shape of the follower shall be of such a design as to provide positive confinement of the gasket.

TM-4.1.4.6 Drain Valve

Two (2) drain valves with hand wheel, at least 150 mm diameter shall be provided at main valve upstream and main valve downstream to drainage pit of main valve chamber.

All pipe, valves and fittings shall be at least PN6.

TM-4.1.4.7 Operating Mechanism

a) General

The rods shall be straight and true, and shall be of chromium-plated forged steel. Each connecting rod shall be attached to a gear and lever, which shall be keyed to the main valve shaft.

b) Valve Disc Position Indication

A mechanical position indicator shall be provided, mounted on the valve body to show the position of the disc.

TM-4.1.4.8 Pressure gauges

Two (2) pressure gauges shall be installed upstream and downstream of main valve. Internal pressure shall be shown to the operator in order to make a decision to open the valve.

The guard valve shall be manual gate valve type for closing to maintenance pressure gauge.

All pipes, valves and fittings shall be at least PN6.

TM-4.1.5 Material**TM-4.1.5.1 General**

All materials shall be of the highest grade, free from defects and imperfections, of recent manufacture and unused, and of the classification and grades designated, conforming to the requirements of the latest issue of the appropriate Specifications cited herein. If the manufacturer desires to deviate from the Standards or Specifications designated, or furnish materials under equivalent standards and classification, the Contractor shall submit a statement at the time of Bid of the exact nature of the deviation, or equivalent standards, and shall submit for the approval of the Engineer, complete with Specifications for the materials which he intends to use. All materials, supplies, and articles not fabricated by the manufacturer shall be the products of recognized reputable manufacturers.

TM-4.1.5.2 Iron Casting

Iron casting shall conform to the requirements of ASTM A 48, Gray Iron Castings, Class 30.

TM-4.1.5.3 Steel Casting

Steel castings shall conform to the requirement of ASTM A 27, Grade 65-35, or better.

TM-4.1.5.4 Steel Forging

Steel forging shall have physical properties at least equal to those required by ASTM A 668, Steel Forgings, Carbon and Alloy for General and Industrial Use, Class D.

TM-4.1.5.5 Steel Plate

Steel plates for the valve body, disc and transition sections shall conform to ASTM A 285, Pressure Vessel Plates, Carbon Steel, Low and Intermediate Tensile Strength, Grade B, if the required plate thickness does not exceed 50 mm, and to ASTM A 516, Carbon Steel plates for Pressure Vessels Intermediate and Higher Temperature Service, Grade 55 or 60, or ASTM A 537 Pressure Vessel Plates, Heat Treated Carbon-Manganese-Silicone, Class 1 Normalized, if the required plate thickness is in excess of 50 mm.

Steel plates for other unimportant stress carrying parts shall conform to ASTM A 36.

TM-4.1.5.6 Corrosion-Resisting Steel**a) Pin and Rod**

Except as otherwise specified, corrosion-resisting pins and rods shall conform to the requirements of ASTM A 276, Stainless and Heat Resisting Steel Bars and Shapes, Type 410 or 302.

b) Bolt and Nut

Corrosion-resisting steel for bolts, screws, nuts and washers shall conform to the requirements of ASTM A 193, Alloy-Steel Bolting Materials for High-Temperature Service, Grade B8 (AISI Type 304).

c) Plate

Corrosion-resisting steel plate for miscellaneous parts shall conform to the requirements of ASTM A 240, Chromium and Chromium-Nickel Stainless Steel Plate, Sheet and Strip for Fusion- Welded Unfired Pressure Vessels, Type 405 or 410.

d) Casting

Corrosion-resisting steel for castings shall conform to the requirements of ASTM A 296, Corrosion Resistant Iron-Chromium, Iron-Chromium-Nickel and Nickel Base Alloy Castings for General Application, Grade CA-15 or CA-6NM.

TM-4.1.5.7 Anchor

Embedded anchor bolts, nuts and washers shall conform to the requirements of ASTM A 325, High-Strength Bolts for Structural Steel Joints, Including Suitable Nuts and Plain Hardened Washers. Anchor plates shall conform to the requirements of ASTM A 36, Structural Steel.

TM-4.1.5.8 Bronze**a) Bronze casting**

Bronze casting shall be of a quality conforming to ASTM B 584, Copper Alloy Sand Castings, for General Applications, Copper Alloy No. 903.

b) Bearing, Wearing Plate and Ring

Bronze bearings, bushings, thrust discs, wearing plates and packing box wearing rings shall conform to SAE 64, Phosphor Bronze Castings, or ASTM B 584, Copper Alloy Sand Castings for General Applications, Copper Alloy No. 937.

c) Bolt and Nut

Bronze bolts and nuts shall conform to the requirements of ASTM B 21, Naval Brass Rod, Bar and Shapes, Alloy No. 464.

TM-4.1.5.9 Bearing

Antifriction bearings shall meet the requirements of and be identified in accordance with the current AFBMA Standards.

TM-4.1.5.10 Seal

a) The rubber seal

The rubber seals shall be molded only and the materials shall be compounded of natural rubber or a copolymer of butadiene and styrene or a blend of both and shall contain reinforcing carbon black, zinc oxide, accelerators, antioxidants, vulcanizing agents and plasticizers. Physical characteristics shall meet the following requirements.

<u>Physical Test</u>	<u>Test Value</u>	<u>Test Method Specifications</u>
Tensile strength	210 kg/cm ² (min)	ASTM D 412
Durometer hardness (Shore Type A)	60 to 70	ASTM D 2240

TM-4.1.6 Tolerance

a) General

All tolerances, allowances and fit shall conform to ANSI B4.1, Preferred Limits and Fits for Cylindrical Parts, for the class of fit required. In general, tolerances for machined finished surfaces shall be within 1.5 mm. Contact or bearing surfaces shall be finished true and exact to secure full contact. Journal surfaces shall be polished and all surfaces shall be finished with sufficient smoothness and accuracy to ensure proper operation when assembled. Parts shall be carefully and accurately machined and like parts shall be interchangeable. Drilled holes for bolts shall be accurately located and drilled from templates.

b) Finished Surface

Where surface finishes are specified herein, the finishes shall be in accordance with ANSI B46.1, Surface Texture. Compliance with specified surface finish shall be determined by sense of feel and by visual inspection of the work compared to Roughness Comparison Specimens. Values of roughness width and waviness height shall be consistent with the general type of finished specified. Where the finish is not indicated or specified, the type of finish shall be that which is most suitable for the surface to which it applies and shall be consistent with the class of fit required.

c) Unfinished Surface

The work shall be laid out so as to secure proper matching of adjoining, unfinished surfaces.

Where there is a large discrepancy between adjoining surfaces they shall be chipped and ground smooth or machined to secure proper alignment. Unfinished surfaces shall be true the lines and dimensions shown on the drawing and shall be chipped or ground

free of all projections and rough spots. Depressions or holes not affecting the strength or usefulness of the parts may be filled in a manner approved by the Engineer.

TM-4.1.7 Welding

Welding shall be carried out in accordance with the description of TG-12 Welding.

TM-4.1.8 Painting

The whole main valve shall be shop painted following the painting schemes as described in TG-14 Painting.

TM-4.1.9 Inspection and Test

TM-4.1.9.1 Shop Test

a) Dimension Inspection

Main dimensions including concentricity and flatness deviation of each component for main valve shall be measured and recorded.

b) Shop Assembly

Set of main valve shall be assembled at shop. After completion of shop assembly, the operating pressure, sealing ring and servomotor stroke shall be measured and recorded. All assembled components shall be properly match-marked and/or doweled including temporary doweled where necessary for final reaming at site to insure accurate reassembly and alignment at site.

c) Hydraulic Pressure Withstand Test

As per EGAT requirement, the spiral case, hydraulic servomotor cylinders, PRV, heat exchangers, pressure tank/air receiver and cooling water strainers or filters shall be hydrostatically tested conforming ASME Boiler and Pressure Vessel Code, Section VIII, Division I.

TM-4.1.9.2 Field Test

Tests shall be conducted at site to determine the performance operating characteristics of the valve and to confirm whether or not the guarantees have been met. Tests on the valve shall be as follows.

a) Alignment check on valve foundation and flexible coupling in dry

b) Operation test in dry and wet

c) Leakage test with valve closure. The amount of leakage shall not exceed 100 cm³/min

d) Proving of interlocks and indications

e) Other tests required by the Engineer

The Contractor shall provide all necessary equipment and instrument for the tests.

TM-4.1.10 Required Spare Parts

All required parts shall be interchangeable with, and of the same materials and workmanship as, the corresponding parts of the main valve.

The Contractor shall furnish the following commissioning required parts for the main valve.

- 1) Rubber ring and other packing one (1) complete set

One complete set of commissioning required parts described above is defined as the total number of the parts required for one unit of the equipment specified in this Chapter. Each type of commissioning required parts stands for the different parts in sizes, pressure or current ratings, functions, etc.

TM-4.2 INLET VALVE (IF APPLICABLE)

TM-4.2.1 General

This section specified the detailed requirements of inlet valve complete with all mechanical, electrical and hydraulic components. In case of the Contractor proposes a Francis turbine, an inlet valve must also be provided.

TM-4.2.2 Type and Description

The inlet valve shall be of the biplane butterfly type with horizontal shafts and counterweight. The minimum acceptable size for the butterfly valve is 1,600 mm. The valve body and disc shall be so proportioned and sized that, when fully open, there will be minimum obstruction to flow of water. The design of the valve body and transition section shall be such as to adequately resist the hydraulic forces acting directly on the body and transition section, and those resulting from the thrust of the disc when in a closed position. The body shall be properly ribbed circumferentially to ensure sufficient rigidity to minimize deformation. A flexible coupling shall be provided between the downstream flange of the valve and spiral case inlet. The valve shall be a standard, manufactured type to ensure interchangeability of parts. An automatic air release valve with manual stop valve shall be provided downstream of the inlet valve.

Closure of the valve shall be by counterweight and opening by the action of hydraulic cylinder.

Each valve assembly shall include but not necessarily be limited to

- a) One (1) valve body assembly, including valve body, disc, shaft and counterweight, together with greaseless bearings, adjustable seals and appurtenances.
- b) One (1) hydraulic operating mechanism, including cylinder, necessary mechanical linkages, and a mechanical locking device.
- c) One (1) control system, including control console, electro-hydraulic control, sensing and indicating devices, control piping and devices for remote indication.
- d) One (1) bypass assembly, with piping, motor or hydraulic operated valve, guard valve and control equipment.
- e) One (1) set of transition sections, if applicable

- f) One (1) flexible coupling between downstream flange of the inlet valve and the spiral case inlet.
- g) One (1) Air valve between downstream flange of the inlet valve and the spiral case inlet.
- h) Additional features and accessories as specified or required, including anchor bolts, nuts, washers, suitable lifting devices and support beams.

TM-4.2.3 Design Criteria

The valve shall normally be closed or opened under equalizing pressure across the disc. However, in case of the turbine failure, under all operating conditions the valve shall be able to shut off water under all operating conditions.

The valve shall be closed by the use of counterweight, against the maximum head and water discharge with normal working stresses in all parts.

The opening time shall be approximately 2 minutes. The closing time shall be step-less adjustable from 1 to 2 minutes. The rate of movement shall be retarded near the end position for both opening and closing strokes. Restrictive orifices shall be located at the oil outlet on the hydraulic cylinder to limit the valve closing time to a minimum of one (1) minute in case of breakage of the hydraulic line.

The valve shall normally be opened only after a pressure equalization across the disc. A differential pressure switch shall be provided in the control circuit to prevent the valve opening if the differential pressure is above 2 meters.

The valve shall be designed for the following conditions.

- | | |
|--------------------------------|--|
| - Maximum design pressure | Not be less than 1.1 times of maximum pressure in penstock |
| - Maximum pressure of penstock | To meet the requirement in TM-1.4 |

Fluid velocity in the hydraulic oil system shall not be more than 4 m/s.

The operating cylinder shall be sized to open the valve with minimum system oil pressure and to retard closing under the most adverse combination of counterweight force and hydraulic torque on the valve disc due to emergency closure at maximum turbine discharge without exceeding the cylinder design pressure.

All parts subject to the maximum hydraulic pressure, shall be in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, Division 1. The allowable stresses for non-pressurized steel parts shall not exceed the values of the AISC Specifications for the design, fabrication and installation of structural steel for buildings.

A 2 mm. corrosion allowance shall be added for the transition sections and the valve body and disc.

In the design of the hydraulic cylinder and piping, the allowable stresses under maximum pressure, including water hammer, shall not exceed one-half (1/2) of the yield stress or one-fourth (1/4) of the ultimate stress.

TM-4.2.4 Description of Components

TM-4.2.4.1 Valve Body

The valve body shall be of normalized cast steel or stress relieved welded steel, and shall have a corrosion-resistant sealing seat of a type to receive the rubber seal. The valve body shall be machine finished where required for matching parts, and drilled to receive the shaft bearings. The body shall be flanged on both ends, and the flanges shall be faced, shop-drilled and spot faces. The drilling shall match the drilling of the companion flanges for the transition sections.

Pads shall be provided on the valve body for transmitting the vertical load to the concrete foundation. Suitable beams and anchor plates and bolts for securing the valve in position shall be provided. The body and transition sections shall be so arranged that no weight or vertical thrust from the valve, transition section or contained water is applied to the spiral case. The support pads shall be of a type to permit adequate movement in the upstream and downstream directions for the valve opening or closure.

TM-4.2.4.2 Valve Disc, Shaft and Seal

The disc shall be of the biplane type, made of normalized cast steel or stress relieved welded steel, and shall be so designed and constructed as to produce a minimum of hydraulic loss. The disc shall be of streamline section to minimize local eddy currents and sudden velocity changes. All surfaces of the disc in contact with water shall be smooth and free from hollows, depressions, cracks or projections that might cause pitting due to cavitation.

The disc and shaft shall be designed to adequately resist the forces acting directly on the disc when in closed position, with utmost rigidity to ensure a minimum of deformation. The disc and shaft may be integrally cast. If not integrally cast, the disc shall be bored and key seated to receive the shaft, which shall be held in position by keys and pins. The valve disc shall be designed and machined to accommodate the valve seal. The seal shall be of rubber or synthetic polymer. The seal retainers and seal fasteners shall be of suitable corrosion-resisting steel. The seals shall be designed and constructed of such materials that they will provide maximum tightness, minimum maintenance and convenient adjustment and replacement. The adjustment feature may be accomplished either in the seal retaining elements or in the seal seating element from the downstream side of the valve. The disc shall be of sufficiently rigid construction and the sealing surfaces shall be so designed that there shall be no jamming when water is drained from the penstock after closure under full head.

TM-4.2.4.3 Valve Bearing

The bearings shall be of a greaseless type. The bearing design shall be such that no water leakage.

TM-4.2.4.4 Bypass Assembly

The bypass assembly shall include one (1) motor or hydraulic pressure operated valve with auxiliary manual operating mechanism, one (1) manual guard valve, piping flanges, fittings, bolts and gaskets. The manual guard valve shall be gate type and located on the upstream side of the motor or hydraulic pressure operated valve.

A 0 to 60 second timer shall be provided to adjust the relation of the inlet valve opening and the bypass valve closing.

All pipe, valves and fittings shall be at least PN6.

TM-4.2.4.5 Flexible Coupling

The flexible couplings shall be gasketed, sleeve type, with diameter to properly fit the pipe. The coupling shall consist of one (1) steel middle ring, of thickness and length as required, two (2) steel followers, two (2) rubber-compounded, wedge-section gaskets and sufficient number of bolts to properly compress the gaskets.

The middle ring shall be of mill-contoured section with longitudinal joints. The finished ring shall be a true circular section, free from irregularities, flat spots or surface defects. The followers shall be of mill-contoured section. They shall be of such strength to accommodate the number of bolts necessary to obtain adequate gasket pressure without excessive rolling. The shape of the follower shall be of such a design as to provide positive confinement of the gasket.

TM-4.2.4.6 Air Valve

A double acting air valve of at least 100 mm nominal bore shall be provided on the downstream of inlet valve to facilitate respectively to supply or release adequate quantity of air during emptying or filling the spiral casing. The details of valve offered such as vacuum pressure at which the valve operate, the location of its mounting, size of orifice provided with details.

All pipe, valves and fittings shall be at least PN6.

TM-4.2.4.7 Operating Mechanism

a) General

The operating mechanism shall consist of hydraulic cylinder and counterweight, arranged to operate the valve properly. The valve shall be held open by hydraulic pressure in the cylinder only, closing on loss of pressure. Provision shall be made to manually lock the disc in the closed position. All pilot and control valves, limit switches and interlocks necessary to coordinate the operation of the lock with the main valve and bypass valve sequence of operation shall be provided. When the valve is locked in the closed position the electric circuits for opening the valve shall be inoperative. Provision shall also be made for padlocking the locking device when in the closed position. Also, with the padlock removed, a locking pin shall be engaged or disengaged by means of a suitable hand lever. The locking pin shall be capable of holding the main valve in the close position against full cylinder force. The locking device shall be so designed that it cannot be locked when the main valve is in the open position.

b) Cylinder

The cylinder shall be fabricated of welded plate or seamless pipe. Flanges shall be of forged steel and shall be provided with suitable gaskets or seal rings designed to remain oil-tight at maximum pressures. The rod end flanges shall contain a bronze bushing with Chevron packing. The cylinder bores shall be honed to a polished finish.

c) Pistons and Ring

The pistons shall be of cast steel and shall be supplied with approved V type packing, and with metal piston rings suitable for the required oil pressure service.

d) Piston Rod

The rods shall be straight and true, and shall be of chromium-plated forged steel. Each connecting rod shall be attached to a lever, which shall be keyed to the main valve shaft.

e) Counterweight

The counterweight shall be sized to provide net closing torque on the disc under all possible operating conditions, and shall be fabricated of steel or cast iron.

f) Limit Switch

Limit switches shall be provided to electrically indicate the open and closed positions of each valve.

TM-4.2.4.8 Hydraulic Oil System

a) General

The inlet valve shall be provided with hydraulic pressure from the governor oil system. A separate accumulator tank (if applicable) shall be provided complete with all electric and hydraulic control required for the complete operation of the inlet valve.

b) Functional Requirements

On a signal to open, oil from the governor oil system or accumulator tank (if applicable) shall be directed through a flow control valve to the valve cylinder. On a signal to close, the oil shall be directed through a flow control valve to the unit governor oil sump tank. The control device will limit the rate of closure of the valve through dashpot action of the hydraulic cylinder.

c) Accumulator Tank (if applicable)

The accumulator tank shall be designed according to ASME Boiler and Pressure Vessel Code, Section VIII and IEC61362. The accumulator tank shall be designed for a maximum allowable working pressure as selected by the Contractor and shall include all required pressure and level control devices. The accumulator tank shall be sized to open the inlet valve once from minimum oil level without any additional oil from the unit governor accumulator tank. A safety valve shall be supplied and set in accordance with ASME Boiler and Pressure Vessel Code, Section VIII.

TM-4.2.4.9 Control Panel

a) General

The control system of the inlet valve shall be integrated with unit control and displayed in the control room.

b) **Operating Control and Indication**

The following controls and indication shall be provided in the control panel.

- i) A flashing lamp to indicate the opening sequence, and remain ON when valve is open.
- ii) A flashing lamp to indicate the closing sequence, and remain ON when valve is closed.
- iii) A lamp to indicate the bypass valve is not in the closed position.
- iv) A lamp to indicate that the differential pressure across the valve disc is greater than acceptable for opening main disc.

c) **Wiring**

All equipment shall be shipped completely wired, except that wiring shall not be installed where it would be disturbed by or for shipment, and shall be arranged for connection to the power supply. Where wiring cannot be properly mounted within assemblies it shall be placed in conduit.

The wire used for control circuit wiring shall be single-conductor, not less than No. 12 AWG, soft-drawn copper, with 600-V wall thickness of synthetic rubber heat and moisture-resisting insulation, with neoprene jacket.

d) **Control Device**

Valve position, limit switch, differential pressure, relays and other control devices shall be furnished as required for the proper operation of the machinery.

TM-4.2.5 Material

TM-4.2.5.1 General

All materials shall be of the highest grade, free from defects and imperfections, of recent manufacture and unused, and of the classification and grades designated, conforming to the requirements of the latest issue of the appropriate Specifications cited herein. If the manufacturer desires to deviate from the Standards or Specifications designated, or furnish materials under equivalent standards and classification, the Contractor shall submit a statement at the time of Bid of the exact nature of the deviation, or equivalent standards, and shall submit for the approval of the Engineer, complete with Specifications for the materials which he intends to use. All materials, supplies, and articles not fabricated by the manufacturer shall be the products of recognized reputable manufacturers.

TM-4.2.5.2 Iron Casting

Iron casting shall conform to the requirements of ASTM A 48, Gray Iron Castings, Class 30.

TM-4.2.5.3 Steel Casting

Steel castings shall conform to the requirement of ASTM A 27, Grade 65-35, or better.

TM-4.2.5.4 Steel Forging

Steel forging shall have physical properties at least equal to those required by ASTM A 668, Steel Forgings, Carbon and Alloy for General and Industrial Use, Class D.

TM-4.2.5.5 Steel Plate

Steel plates for the valve body, disc and transition sections shall conform to ASTM A 285, Pressure Vessel Plates, Carbon Steel, Low and Intermediate Tensile Strength, Grade B, if the required plate thickness does not exceed 50 mm, and to ASTM A 516, Carbon Steel plates for Pressure Vessels Intermediate and Higher Temperature Service, Grade 55 or 60, or ASTM A 537 Pressure Vessel Plates, Heat Treated Carbon-Manganese-Silicone, Class 1 Normalized, if the required plate thickness is in excess of 50 mm.

Steel plates for other unimportant stress carrying parts shall conform to ASTM A 36.

TM-4.2.5.6 Corrosion-Resisting Steel

a) Pin and Rod

Except as otherwise specified, corrosion-resisting pins and rods shall conform to the requirements of ASTM A 276, Stainless and Heat Resisting Steel Bars and Shapes, Type 410 or 302.

b) Bolt and Nut

Corrosion-resisting steel for bolts, screws, nuts and washers shall conform to the requirements of ASTM A 193, Alloy-Steel Bolting Materials for High-Temperature Service, Grade B8 (AISI Type 304).

c) Plate

Corrosion-resisting steel plate for miscellaneous parts shall conform to the requirements of ASTM A 240, Chromium and Chromium-Nickel Stainless Steel Plate, Sheet and Strip for Fusion- Welded Unfired Pressure Vessels, Type 405 or 410.

d) Casting

Corrosion-resisting steel for castings shall conform to the requirements of ASTM A 296, Corrosion Resistant Iron-Chromium, Iron-Chromium-Nickel and Nickel Base Alloy Castings for General Application, Grade CA-15 or CA-6NM.

TM-4.2.5.7 Anchor

Embedded anchor bolts, nuts and washers shall conform to the requirements of ASTM A 325, High-Strength Bolts for Structural Steel Joints, Including Suitable Nuts and Plain Hardened Washers. Anchor plates shall conform to the requirements of ASTM A 36, Structural Steel.

TM-4.2.5.8 Bronze

a) Bronze casting

Bronze casting shall be of a quality conforming to ASTM B 584, Copper Alloy Sand Castings, for General Applications, Copper Alloy No. 903.

b) Bearing, Wearing Plate and Ring

Bronze bearings, bushings, thrust discs, wearing plates and packing box wearing rings shall conform to SAE 64, Phosphor Bronze Castings, or ASTM B 584, Copper Alloy Sand Castings for General Applications, Copper Alloy No. 937.

c) Bolt and Nut

Bronze bolts and nuts shall conform to the requirements of ASTM B 21, Naval Brass Rod, Bar and Shapes, Alloy No. 464.

TM-4.2.5.9 Bearing

Antifriction bearings shall meet the requirements of and be identified in accordance with the current AFBMA Standards.

TM-4.2.5.10 Hydraulic Oil System

a) Pipe and Tubing

Main pressure pipe shall be seamless steel tubing. Tubing shall conform to the requirements of ASTM A 519, Seamless Carbon and Alloy Steel Mechanical Tubing. All other pipes shall conform to the requirements of ASTM A 106, Seamless Carbon Steel Pipe for High-Temperatures Service, Grade B. Flanges shall conform to the requirements of ASTM A 181, Forged or Rolled Steel Pipe Flanges, Forged Fittings, and Valves and Parts for General Service, Grade I.

b) Fitting

Fittings for tubing shall conform to the requirements of SAE 1020. Fittings for pipe shall be of the socket-welded type and shall conform to the requirements of ASTM A 234, Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures.

c) Lubricating System

Lubricant lines shall be seamless copper tubing conforming to ASTM B 68, Seamless Copper Tube, Bright Annealed, with brass fittings of suitable pressure rating.

TM-4.2.5.11 Seal

a) The rubber seal

The rubber seals shall be molded only and the materials shall be compounded of natural rubber or a copolymer of butadiene and styrene or a blend of both and shall contain

reinforcing carbon black, zinc oxide, accelerators, antioxidants, vulcanizing agents and plasticizers. Physical characteristics shall meet the following requirements.

<u>Physical Test</u>	<u>Test Value</u>	<u>Test Method Specifications</u>
Tensile strength	210 kg/cm ² (min)	ASTM D 412
Durometer hardness (Shore Type A)	60 to 70	ASTM D 2240

b) Hydraulic Seal

V type packing shall be Chevron type and materials compatible with water and the oil used, and suitable for the operating pressures and temperatures.

TM-4.2.6 Tolerance

a. General

All tolerances, allowances and fit shall conform to ANSI B4.1, Preferred Limits and Fits for Cylindrical Parts, for the class of fit required. In general, tolerances for machined finished surfaces shall be within 1.5 mm. Contact or bearing surfaces shall be finished true and exact to secure full contact. Journal surfaces shall be polished and all surfaces shall be finished with sufficient smoothness and accuracy to ensure proper operation when assembled. Parts shall be carefully and accurately machined and like parts shall be interchangeable. Drilled holes for bolts shall be accurately located and drilled from templates.

b. Finished Surface

Where surface finishes are specified herein, the finishes shall be in accordance with ANSI B46.1, Surface Texture. Compliance with specified surface finish shall be determined by sense of feel and by visual inspection of the works compared to Roughness Comparison Specimens. Values of roughness width and waviness height shall be consistent with the general type of finish specified. Where the finish is not indicated or specified, the type of finish shall be that which is most suitable for the surface to which it applies and shall be consistent with the class of fit required.

c. Unfinished Surface

The work shall be laid out so as to secure proper matching of adjoining, unfinished surfaces.

Where there is a large discrepancy between adjoining surfaces they shall be chipped and ground smooth or machined to secure proper alignment. Unfinished surfaces shall be true the lines and dimensions shown on the drawing and shall be chipped or ground free of all projections and rough spots. Depressions or holes not affecting the strength or usefulness of the parts may be filled in a manner approved by the Engineer.

TM-4.2.7 Welding

Welding shall be carried out in accordance with the description of TG-12 Welding.

TM-4.2.8 Painting

The whole inlet valve shall be shop painted following the painting schemes as described in TG-14 Painting.

TM-4.2.9 Inspection and Test**TM-4.2.9.1 Shop Test****a) Dimension Inspection**

Main dimensions including concentricity and flatness deviation of each component for inlet valve shall be measured and recorded.

b) Shop Assembly

Set of inlet valve shall be assembled at shop. After completion of shop assembly, the operating pressure, sealing ring and servomotor stroke shall be measured and recorded. All assembled components shall be properly match-marked and/or doweled including temporary doweling where necessary for final reaming at site to insure accurate reassembly and alignment at site.

c) Hydraulic Pressure Withstand Test

As per EGAT requirement, the spiral case, hydraulic servomotor cylinders, PRV, heat exchangers, pressure tank/air receiver and cooling water strainers or filters shall be hydrostatically tested conforming ASME Boiler and Pressure Vessel Code, Section VIII, Division I.

TM-4.2.9.2 Field Test

Tests shall be conducted at site to determine the performance operating characteristics of the valve and to confirm whether or not the guarantees have been met. Tests on the valve shall be as follows.

- a) Alignment check on valve foundation and flexible coupling in dry
- b) Operation test in dry and wet
- c) Leakage test with valve closure. The amount of leakage shall not exceed 100 cm³/min
- d) Proving of interlocks and indications
- e) Investigation of any objectionable vibration, pressure surge or noise under any operating condition
- f) Servomotor pressure differential test over complete stroke
- g) Emergency closure test with unit at full load
- h) Other tests required by the Engineer

The Contractor shall provide all necessary equipment and instrument for the tests.

TM-4.2.10 Required Spare Parts

All required parts shall be interchangeable with, and of the same materials and workmanship as, the corresponding parts of the inlet valve.

The Contractor shall furnish the following commissioning required parts for the inlet valve.

- 1) Rubber ring and other packing one (1) complete set

One complete set of required parts described above is defined as the total number of the parts required for one unit of the equipment specified in this Chapter. Each type of commissioning required parts stands for the different parts in sizes, pressure or current ratings, functions, etc.

TM-4.3 IRRIGATION VALVE (NOT APPLICABLE)

TM-4.4 HIGH PRESSURE SLIDE GATE

TM-4.4.1 General

This section specified the detailed requirements of a high pressure slide gate set. The set is comprised with one (1) guard gate and one (1) regulating gate completed with hydraulic operating mechanism.

The operator shall be able to operate open/close guard gate and regulating gate from local control panel or via HMI screen at control room which as same as local control panel. Gate position indicator, gate position feedback, alarms and protection shall be provided

The automatic restoring shall be provided to restore the gate to its designed opening position at all time.

TM-4.4.2 Type and Description

One (1) guard gate shall be of hydraulic cylinder operating with oil pump driven by electric motor 380 V., 3 Phase, 50 Hz. The minimum acceptable size for guard gate is 1,800 mm x 1,800 mm. The function is to fully close/open when maintenance is required.

An automatic air release valve with manual stop valve shall be provided downstream at guard gate.

One (1) regulating gate shall be of hydraulic cylinder Operating with oil pump driven by electric motor 380 V., 3 Phase, 50 Hz. The minimum acceptable size for Guard gate is 1,800 mm x 1,800 mm. The function is to regulate or control the flow rate of the water released downstream.

In case of power failure occurred, hand pump operating is required.

Gate assembly shall include but not necessarily be limited to

- a) One (1) set of upstream, middle and downstream transition

- b) One (1) guard gate assembly, including upstream frame, downstream frame, gate body, seals, mechanical locking device and cylinder
- c) One (1) regulating gate assembly, including upstream frame, downstream frame, gate body, seals, mechanical locking device and cylinder
- d) One (1) hydraulic oil system including oil sump tank, oil pump driven by electric motor, hand operated oil pump, piping, valves, fitting, instrument and protective devices for regulating both guard gate and regulating gate.
- e) One (1) set of control system for Hydraulic oil system
- f) One (1) bypass assembly, with piping, manually operated valve and manual stop valve for Guard gate
- g) Two (2) sets of pressures gauges and manual stop valve for operating guard gate
- h) Two (2) drain valves at upstream and downstream of the Guard gate.
- i) One (1) Air valve and gate valve at downstream flange of the Guard gate

TM-4.4.3 Design Criteria

The guard gate shall normally be closed or opened under equalizing pressure across the slide gate. However, the gates shall close under gravity either as a normal operating under no-flow conditions, or, in an emergency, against maximum flow through the conduit.

The regulating shall normally be raised against maximum unbalanced head and allowing the gate to close under gravity against maximum flow.

The gates shall be designed conforming to AWWA C560.

The gate shall be designed for the following conditions.

- | | |
|-----------------------------|---|
| - Maximum design pressure | Not be less than 1.1 times of maximum pressure in gates |
| - Maximum pressure of gates | To meet the requirement in TM-1.4 |

All parts subject to the maximum hydraulic pressure, shall be in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, Division 1. The allowable stresses for non-pressurized steel parts shall not exceed the values of the AISC Specifications for the design, fabrication and installation of structural steel for buildings.

A 2 mm. corrosion allowance shall be added for the transition sections and frame and gate body.

TM-4.4.4 Hydraulic Oil System

- a) The contractor shall provide one (1) oil pressure unit system (OPU system) for regulating both of Guard gate and Regulating gate. The OPU system shall consist of an oil hydraulic

cylinder, oil pumping unit, hand pump, oil reservoir tank and control cabinet complete with hydraulic and electric controls.

- b) The hydraulic cylinder of the gates shall be designed conforming to AWWA C541

TM-4.4.5 Welding

Welding shall be carried out in accordance with the description of TG-12 Welding.

TM-4.4.6 Painting

The whole main valve shall be shop painted following the painting schemes as described in TG-14 Painting.

TM-4.4.7 Inspection and Test

TM-4.4.7.1 Shop Test

- a) Dimension Inspection

Main dimensions including concentricity and flatness deviation of each component for inlet valve shall be measured and recorded.

- b) Shop Assembly

Set of gates shall be assembled at shop. After completion of shop assembly, the operating pressure, sealing ring and servomotor stroke shall be measured and recorded. All assembled components shall be properly match-marked and/or doweled including temporary doweling where necessary for final reaming at site to insure accurate reassembly and alignment at site.

- c) Hydraulic Pressure Withstand Test

As per EGAT requirement, the spiral case, hydraulic servomotor cylinders, PRV, heat exchangers, pressure tank/air receiver and cooling water strainers or filters shall be hydrostatically tested conforming ASME Boiler and Pressure Vessel Code, Section VIII, Division I.

TM-4.4.7.2 Field Test

Tests shall be conducted at site to determine the performance operating characteristics of the valve and to confirm whether or not the guarantees have been met. Tests on the valve shall be as follows.

- a) Alignment check on gates foundation
- b) Operation test in dry and wet
- c) Leakage test with gate closure.
- d) Proving of interlocks and indications

- e) Investigation of any objectionable vibration, pressure surge or noise under any operating condition
- f) Emergency closure test
- g) Other tests required by the Engineer

The Contractor shall provide all necessary equipment and instrument for the tests.

TM-4.5 INTAKE GATE/STOPLOGS (NOT APPLICABLE)

TM-4.6 DRAFT TUBE GATE/STOPLOGS (NOT APPLICABLE)

End of Chapter

DRAFT

TM-5 MECHANICAL AUXILIARY EQUIPMENT

EQUIPMENT WORKS

MECHANICAL EQUIPMENT - TECHNICAL SPECIFICATIONS

TM-5 MECHANICAL AUXILIARY EQUIPMENT

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TM-5 MECHANICAL AUXILIARY EQUIPMENT

TM-5.1 GENERAL

This section specified the detailed requirements of mechanical auxiliary equipment. All valves, piping, electrical equipment and other control devices required to make each system function properly shall be included in the scope of supply of each equipment.

TM-5.1.1 Work Included

The equipment covered under this section is for the following systems.

- Drainage and dewatering system
- Cooling water supply system
- Compressed air supply system
- Fire extinguisher
- Domestic water supply system
- Water level measuring device
- Ventilation and air conditioning equipment

TM-5.1.2 Codes and Standards

All materials, equipment and methods of the works shall comply with the latest edition of applicable laws, codes and standards including, but not limited to, the following:

- American National Standard Institute (ANSI)
- American Society of Mechanical Engineers (ASME)
- American Society for Testing and Materials (ASTM)
- American Welding Society (AWS)
- Factory Mutual Engineering Corporation (FM)
- National Plumbing Code, ANSI A40.8
- Underwriters' Laboratories Inc. (UL)
- Crane manufacturers Association of America (CMAA)
- American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)

TM-5.2 DRAINAGE AND DEWATERING SYSTEM

TM-5.2.1 General

The drainage pit shall consist of two (2) submersible pumps, piping, valves and control equipment for drainage and dewatering of water to tailwater as shown on the drawings. The Contractor shall be fully responsible for the design of the system.

TM-5.2.2 Type and Construction

Two (2) drainage pumps, submersible pump, centrifugal type sump pump, directly coupled induction motor driven, (two (2) for normal use automatic lead/leg control) shall be supplied. Pump discharge connection system shall be quick gravity connection system. The motor specification shall be according to the requirements outlined in TG-10 Electrical Equipment. The overall efficiency shall be not less than 50 %.

The accessories and other auxiliary equipment which are not specifically mentioned in this Clause or indicated on the drawings, but are necessary or usual for the satisfactory operation shall be provided by the Contractor at his own expense.

TM-5.2.3 Operation and Control Device

The control for the pumps shall be of a lead/lag operation type and shall be capable of manual and automatic operation. The start/stop of the pumps shall be controlled by float switches located inside the drainage pit. The float switches shall be of adjustable level type and shall be suitable for submerged operation. The float switches shall be mounted in a vertical steel pipe. As well, the float switch pipe complete with float switches shall be arranged so that it can be easily removed from the drainage pit.

TM-5.2.4 Piping System

The Contractor shall be fully responsible for the detail design of piping. All pipes, flanges, valves, bolts, nuts, washers, etc. shall be made of galvanized steel pipe or high-density polyethylene pipe (HDPE), Piping shall be deemed to include as required, discharge pipe, fittings, guide hangers, supports, anchors and others.

TM-5.2.5 Inspection and Test

After completion of all installation works, the following inspections and tests shall be completely carried out.

- a) Leakage inspection and test
- b) Functional test of float switches
- c) Pump discharge test

TM-5.3 COOLING WATER SUPPLY SYSTEM

TM-5.3.1 General

The Contractor shall provide Close Loop Cooling water supply system (if required) for supply to, and where necessary, discharge from each item of equipment requiring cooling water while the unit is operating. The system shall be in accordance with the manufacturer's design and required to submit for EGAT's approval. The Schematic diagram shall be submitted with Bids according to Clause IB-15.

In case the Contractor proposes Once Through Cooling water system. It shall consist of equipment as following in TM-5.3.3 Type and Construction of Equipment (for Once Through system).

The Close Loop Cooling water supply system shall supply for the following.

- i) Generator air cooler (if required)
- ii) Generator bearing oil cooler (if required)
- iii) Turbine bearing oil coolers (if required)
- iv) Governor oil system (if required)

The Contractor shall provide Once Through Cooling water supply system for shaft seal. The water shall be taken from a tapping on Once Through system pipeline. The system shall consist of, cyclone sand separator, Shaft seal strainer, isolating valves, flow control valves, measuring instrument, piping, valves and control equipment.

The envisaged schematic arrangement of the cooling water supply system is shown on the drawings. The details shown on the drawings shall be taken as the minimum requirement.

The Contractor shall design and specify the flow requirements, size of piping required and the operating head of the system.

All piping and fittings shall be made of galvanized steel pipe.

All piping, valves and fittings shall have a pressure rating of not less than PN6.

All electrical components such as relays, internal wiring shall be conformed to TG-10 – Electrical Equipment.

TM-5.3.2 Arrangement of Equipment

The cooling water supply shall be connected from the penstock.

If deemed necessary by the Contractor, the duplicate pressure reducing valves and relief valves shall be provided.

The strainer piping system shall be capable of supplying the total cooling water requirement of the unit.

An orifice or globe valve for flow distribution adjustment, flow relay for flow indication and flow failure alarm shall be provided in each branch of the all system. The all system shall be completed with all pipes, manual and automatic valves, pressure gauges, air release valve and drains.

TM-5.3.3 Type and Construction of Equipment (for Once Through system)

- a) Cooling water pump with motor (if required)

If pressure in penstock (at minimum reservoir water level) is not sufficient to meet the combined turbine and generator requirements under all operating conditions.

- b) C.W. motor operated valve

One (1) C.W. motor operated valve controlled by turbine start and stop sequences shall be located as close as practicable to the pipeline offtake.

- c) C.W. motor operated strainer

i) One (1) C.W. motor operated strainer shall be provided. The strainer shall be automatically operated self-cleaning type with mesh openings ranging from 500 to 1000 μm and in any case small enough to exclude any foreign matter large enough to cause damage or blocking in any part of the system.

ii) Any discharge from the strainer resulting from a backwash or flushing cycle shall be drained out directly to the tailrace. The mesh shall be of corrosion resistant material and the strainer bodies and covers shall be galvanized internally and externally.

iii) The strainer shall have an automatic air release valve with discharge pipe to drain.

iv) If the required backwash pressure is not sufficient at minimum upstream water level, a small booster pump shall be provided, preferably integral, with the strainer assembly.

v) A high differential pressure switch for remote annunciation in the control room shall be supplied. This shall operate on a high differential pressure across the strainer.

- d) Sand separator

i) cyclone sand separator shall be provided. Each sand separator set shall be sized to match the requirements of the turbine/generator cooling, shaft seal and equipment-cooling water requirements.

ii) The separator shall be capable of removing 98 percent of all particles with mesh openings ranging from 300 to 500 μm .

iii) Operation - One sand separator will be in service at a time with the another one on a backwash cycle. The automatic transfer from one unit to another shall be

initiated by either a differential pressure across the sand separator or by 1-hr to 24-hr adjustable timer. The transfer from one set to the another shall be such that flow to the unit is always maintained during the transfer.

- iv) Backwashing of the separators shall be accomplished by using clean water from the separator discharge side and with appropriate solenoid-operated valves. If the required backwash pressure is not sufficient at minimum upstream water level, a small booster pump shall be provided. This pump may be combined with the strainer booster pump as stated in the above Clause. Backwash water shall be discharged directly to the tailrace.
- e) Shaft seal strainer

One (1) shaft seal motor operated strainer together with the other accessories shall be provided at the inlet of turbine shaft seal line. The turbine manufacturer shall specify the required size, flow and mesh spacing, which shall range from 100 to 300 μm . A low-pressure alarm switch for remote annunciation shall be supplied. The alarm shall indicate when a strainer is fouled up. The Contractor shall specify the required setting of this switch.
- f) Pressure reducing valve (if required)

Pressure reducing valves shall be provided to regulate the pressure of the cooling water to the bearings and shaft seal.

TM-5.3.4 Piping System

The Contractor shall be fully responsible for the detail design of piping. All pipes, flanges, valves, bolts, nuts, washers, etc. shall be made of Galvanized steel pipe. Piping shall be deemed to include as required, discharge pipe, fittings, guide hangers, supports, anchors and others.

All pipe, valves and fittings shall be at least PN6.

TM-5.3.5 Inspection and Test

After completion of all installation works, the following inspections and tests shall be completely carried out.

- a) Leakage inspection and test
- b) Functional test of equipment
- c) Discharge test

TM-5.4 COMPRESSED AIR SUPPLY SYSTEM

TM-5.4.1 General Description

The compressed air supply system shall be supplied with a lead/lag control system for operating air to the following equipment:

- i) Service air 720 kPa for general use

ii) Generator friction brakes (if applicable)

Compressed air system for the generator friction brakes shall be supplied from the operating air system to charge a separate low pressure air receiver via a pressure reducing valve and associated pipe work.

All electrical components such as relays, internal wiring shall be conformed to TG-10 – Electrical Equipment.

TM-5.4.2 Arrangement of Equipment

The system shall comprise one (1) or two (2) motorized air cooled compressors, each with a silencer, intake filter, after-cooler, non-return valve and isolating valve delivering into the governor air receiver. The system shall allow charging of either governor air receiver with any one compressor. The compressors shall be arranged to operate by manual push-button control. The system shall be completed with all pipes, fittings/connections, air filters, safety valves, temperature and pressure gauges as well as pressure switches in which shall be supplied for low and high pressure alarm with signal to the control room.

TM-5.4.3 Compressor

The compressor shall be continuously rated and of a reciprocating, air-cooled pattern.

All working parts shall be replaceable.

The compressor shall be provided with after-cooler and, where necessary inter-coolers. They shall be air-cooled and the tube nests shall be replaceable. The tubes shall be of corrosion resistant material. Each cooler shall be completed with moisture separator and automatic trap fitted with sight glass assembly.

TM-5.4.4 Air Receiver

Compressed Air receiver shall be designed and constructed in accordance with the latest applicable ASME Standards.

The receiver shall be fitted with safety valves, level switch and alarm, pressure switch and alarm, pressure gauges and automatic and manual condensed drains.

TM-5.4.5 Piping System

The Contractor shall be fully responsible for the detail design of piping. All pipes, flanges, valves, bolts, nuts, washers, etc. shall be made of Galvanized steel pipe. Piping shall be deemed to include as required, discharge pipe, fittings, guide hangers, supports, anchors and others.

TM-5.5 FIRE EXTINGUISHER

TM-5.5.1 General Description

The fire extinguisher shall consist of rechargeable portable fire extinguishers.

Three (3) sets of rechargeable portable dry chemical extinguishers shall be supplied. The final mounting location shall be indicated by EGAT later on.

TM-5.5.2 Type and Construction

Dry chemical extinguishers shall be of a multi-purpose type suitable for Class A, B and C fires. Each extinguisher shall be a minimum 6.8 kgs capacity (weight of agent).

Extinguishers shall be red with a glossy baked-enamel finish, chrome-plated trim and safety pin. Each shall be completed with a wall-mounting clip.

TM-5.5.3 Inspection and Test

After completion of all installation works, the following inspections and tests shall be carried out.

- Leakage test and inspection
- Function test

TM-5.6 DOMESTIC WATER SUPPLY SYSTEM

The Contractor shall supply piping and valves by tapping from penstock as shown on the attached drawing. The location of tapping point shall be subject to the Engineering approval. Plumbing system shall be referred Part 2, Volume III Civil Works, Clause 2.7.1. Plumbing System.

TM-5.7 WATER LEVEL MEASURING DEVICE

TM-5.7.1 Reservoir

Water level measurement devices for reservoir shall sense the instantaneous inlet pressure immediately by electrodes or ultrasonic detector or approved type. This signal shall convert to two (2) outputs of 4 to 20 mA DC direct reading indicator (reservoir water level (RWL)) scaled in meter at the control room and unit controller (PLC). The device shall be calibrated for elevation.

The devices shall be comprised of detection part and signal transmission part. The signal transmission part shall be accommodated in the local control box. All components in contact with water shall be of corrosion resistance material.

TM-5.7.2 Tailwater

Water level measurement devices for tailwater shall sense the instantaneous inlet pressure immediately by hydrostatic or electrodes or ultrasonic detector or approved type. This signal shall convert to two (2) outputs of 4 to 20 mA DC direct reading indicator (tailwater level (TWL)) scaled in meter at the control room and unit controller (PLC). The device shall be calibrated for elevation.

The devices shall be comprised of detection part and signal transmission part. The signal transmission part shall be accommodated in the local control box. All components in contact with water shall be of corrosion resistance material.

TM-5.8 VENTILATION AND AIR-CONDITIONING EQUIPMENT

The Contractor shall design and supply air conditioning and air ventilation equipment in the powerhouse in accordance with the latest applicable ASHRAE Standard. The equipment shall consist of:

- a) Modern split type air conditioning for the following rooms shall be provided. The calculation of heat load for each room shall be submitted to the Engineer for approval.
 - i) Two (2) sets for control room, (one (1) set for normal use and the other for stand-by)
 - ii) Two (2) sets for electrical room, (one (1) set for normal use and the other for stand-by)

If control room and electrical room can merge in the same room. The Contractor shall supply only two (2) sets of modern split type air conditioning and only one (1) set of ventilated fan for this room.

- b) Individual ventilated fans for the following rooms shall be provided. The calculation of air change per hour required for ventilation in each room shall also be submitted to the Engineer for approval.
 - i) Control room
 - ii) Toilet
 - iii) Electrical room
- c) The air ventilation system for the area of generator floor, turbine floor and equipment room shall be designed by the Contractor. All of the calculation for air change per hour shall also be submitted to the Engineer for approval. The air ventilation system shall include the following:
 - i) Ceiling intake screens, louvers and filter
 - ii) Air ducts and accessories including register grills, vanes
 - iii) Electrical control and instrumentation

The air ventilation system shall be designed for the following conditions:

- a) Power supply: station service power supply of 3 phase 380 V, 50Hz.
- b) Noise and vibration: The air supply equipment shall operate without objectionable noise and vibration in the excess of the values given or in the option of the Engineer.
- c) Rate of air change per hour shall be according to the applicable standard.

All electrical components such as relays, internal wiring shall be conformed to TG-10 – Electrical Equipment.

TM-5.9 CONTROL AND AUXILIARY POWER SUPPLIES

All equipment supplied for the auxiliary mechanical systems shall be suitable for operation on the control and auxiliary power supplies specified in TG-5 Control and Auxiliary Power Supplies.

TM-5.10 ELECTRICAL EQUIPMENT

All electrical equipment associated with auxiliary mechanical systems and equipment herein specified shall meet the requirements in TG-10 Electrical Equipment.

TM-5.11 PAINTING

All painted surfaces of new equipment supplied by the Contractor shall be, as far as is practical, shop painted in accordance with the specifications outlined in TG-14 Painting.

TM-5.12 NAMEPLATE

All new equipment shall be identified, and all nameplate wording shall be subject to EGAT. Nameplates shall be in accordance with the specifications outlined in TG-13 Nameplate and Marking.

TM-5.13 INSPECTION AND TEST

TM-5.13.1 General

All auxiliary mechanical systems shall be subject to inspection and testing as specified in TG-18 Inspection and Tests-Electrical/Mechanical.

All auxiliary mechanical systems shall be factory tested before shipment.

The Contractor shall furnish certified copies of all test results, the results of each test shall be recorded in the form of test certificates or reports as specified in Clause SC-4 Documents to be Prepared by the Contractor.

The Contractor shall provide all necessary special instrumentation for tests.

TM-5.13.2 Type Test

Type tests may be offered by the Contractor as specified in TG-18 Inspection and Tests-Electrical/Mechanical, provided the Contractor gives evidence to EGAT as to the similarity of the equipment tested and the equipment supplied.

TM-5.13.3 Shop Test

The equipment shall be subjected to shop tests as specified in Clause GC-13 Quality Assurance, Inspection and Shop Tests and in accordance with the latest issue of the applicable standards.

In addition, the Contractor shall perform the following shop tests:

a) Material Test

Material tests shall be as specified in TG-18 Inspection and Tests-Electrical/Mechanical.

b) Hydrostatic Test

Hydrostatic tests shall be as specified in TG-18 Inspection and Tests-Electrical/Mechanical.

c) Shop Test

Shop tests as specified in TG-18 Inspection and Tests Electrical/Mechanical.

End of Chapter

TM-6 PENSTOCK AND BIFURCATIONS

EQUIPMENT WORKS

TECHNICAL SPECIFICATION – MECHANICAL EQUIPMENT

TM-6 PENSTOCK AND BIFURCATIONS

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TM-6 – PENSTOCK AND BIFURCATIONS

TM-6.1 GENERAL

The scope of the work of this section consists of the design, manufacture, supply, shop testing, delivery, erection, field testing and commissioning of a penstock and bifurcation as shown on the drawings.

It is not the intention of these specifications to specify in complete detail the various parts of the equipment, it is the responsibility of the Contractor to furnish equipment which will meet, in all respects, the requirements of EGAT in regard to performance, durability and satisfactory operation. However, certain material, features and design requirements are specified herein.

The Contractor shall supply all welding electrodes, all anchor bars and bolts, embedded parts and other fixing devices required for the erection of equipment under this Contract.

The Contractor shall determine the number and locations of supports and shall design and supply all supports required during erection, stress relieving, testing and embedment in concrete of the penstock components.

Drainage pipe and valves shall be provided for dewatering the penstock, directly discharged to tailrace. A final schematic arrangement of all equipment shall be submitted for approval by the Engineer.

TM-6.2 CODES AND STANDARDS

All materials and workmanship shall comply with the requirements of the latest revision of the following codes and standards.

- American Society of Mechanical Engineers (ASME)
- American Society for Testing and Materials (ASTM)
- American Institute of Steel Construction (AISC)
- American Water Works Association (AWWA)
- American Welding Society (AWS)
- International Electrotechnical Commission (IEC)
- Steel Structures Painting Council (SSPC)
- United States Bureau of Reclamation (USBR)

TM-6.3 DOCUMENTS TO BE PREPARED BY THE CONTRACTOR

The Contractor shall undertake the complete study and design necessary for the construction and erection of the equipment at the site. The Contractor shall provide all Contract drawings showing the equipment and related works.

Prior to fabrication of the equipment, the Contractor shall submit detailed drawings to the Engineer for approval in due course. The modified drawings shall be made in order to meet the requirements of the specifications. The Contractor shall submit the modified drawings for approval as well.

The Contractor shall, in addition to the document specified in the Contract, furnish without delay any calculations, documents, drawings and other information, which may be required by the Engineer from time to time during period of the Contract.

The Contractor shall be solely responsible for all discrepancies, errors or omissions in the drawings, documents and etc. submitted by him, even if such drawings and documents have been approved by the Engineer.

TM-6.4 DESIGN CRITERIA

a. General

The Contractor shall be fully responsible for the final design of the penstock and bifurcation to find out the proper characteristics, i.e. diameter and thickness so as to meet the requirements

The penstock and bifurcation shall be designed for the following conditions.

- Maximum design pressure shall not be less than 1.1 times of maximum pressure in the penstock.
- Maximum pressure of the penstock To be estimated and guaranteed by turbine manufacturer but not be less than 49.50 m (TM-1.4)

The Bidding Drawings show the general outline and layout of penstock and bifurcation required for the Contractor's design purposes.

All designs shall be carried out by the Contractor in accordance with the best modern practice and the requirements of these specifications, notwithstanding any omission therein.

The design calculations shall have sufficient detail to show all design criteria used including the stress calculations. All design calculations shall be submitted for approval prior to commencement of the works.

No drainage will be provided to relieve the external pressure that is actually foreseen to have values indicated in the following paragraph.

Penstock and bifurcation shall be self-resistance both to internal and external pressure.

If external anchor bars and bolts or reinforcing supports are foreseen for the penstock and bifurcation their height shall be such as to leave a free distance between them and the excavation line indicated in the drawings. Exceptions to this prescription will not be accepted.

The bifurcation shape shall be in accordance with the bidding drawings. In any case the Contractor shall demonstrate that he has already designed and manufactured bifurcation of the comparable shape and dimensions and that such bifurcation has been mathematical model or physical model tested in order to find out the best shape.

b. Loading and Loading Condition

Not only the penstock but also the existing conduit to be connected shall be designed taking into consideration the loading of the various conditions as below.

Normal Loading Condition

- (i) Maximum internal pressure due to maximum water hammer.
- (ii) Load during penstock filling and dewatering.

Test Loading Condition

- (i) Internal pressure due to hydrostatic testing (where relevant).

Construction Loading Condition

- (i) External pressure due to concrete placement resulting from the following
 - 2 meter maximum lift height
 - 1 meter unbalanced height
 - A pour rate of 1 meter per hour.
- (ii) Load due to handling.
- (iii) Load during backfilling with the penstock empty plus live load from backfill equipment.
- (iv) Load due to thermal expansion and contraction.
- (v) Load from supports during erection and hydrostatic testing.

c. Allowable Stress

For all parts of the work subjected to water pressure, the unit stress in the materials shall be in accordance with the values listed in ASME Boiler and Pressure Vessel Code, Section VIII, Division 1.

Allowable stresses for non-pressurized parts of rolled steel shall not exceed the values of the AISC Specifications for the design, fabrication and installation of structural steel for buildings.

A 2 mm increase in shell plate thickness is required as a corrosion allowance.

Minimum plate thickness of steel plate for penstock diameters 2.3 m. and 1.6 m. shall be not less than 13.0 mm. and 10.0 mm. respectively or shall be proposed by the Contractor to withstand the maximum water hammer from the fast closure guide vanes operation

Minimum plate thickness of steel plate for bifurcation shall be proposed by the Contractor to withstand the maximum water hammer from the fast closure guide vanes operation.

In the design of penstock, the allowable stresses under maximum pressure, including water hammer, shall not exceed one-half (1/2) of the yield stress or one-fourth (1/4) of the ultimate stress.

The penstock components shall be designed as freestanding but continuously supported pipes, with short, unsupported lengths at coupling locations.

External stiffener rings shall be incorporated in the design, augmented by temporary internal bracing as required to maintain the penstock components within the specified tolerances, during testing and concrete placing.

Steel components not subject to hydrostatic testing shall be designed to resist the internal hydraulic pressure without regard to the concrete encasing.

TM-6.5 MATERIAL

All materials shall conform to the following standards unless otherwise specifically approved by the Engineer.

All steel plates for penstock, cylindrical lines and any welded attachment	ASTM A 516 and ASTM A 537 Class 1
Steel for cradles, spiders and etc, which shall not be welded to the steel linings.	ASTM A 36 and ASTM A 283
Anchor bolts and fixing devices.	ASTM A 325

TM-6.6 FABRICATION

- a. Scope

This Clause covers preparation and shaping of individual plates, assembling plates into units within the shop, shop testing, and handling and preparation of the units for transportation.

b. Transportation of Material

The Contractor shall load, transport and unload all equipment and materials in a manner satisfactory to the Engineer throughout the works.

c. Fabrication Schedule and Procedure

Prior to beginning any fabrication, the Contractor shall submit to the Engineer for review a fabrication schedule and fabrication procedure, which shall include a complete description of the fabrication process and layout of facility locations such as the Contractor's permanent shop and field shop at which the separate processes are to be performed.

d. Preparation of Plate

- (i) Prior to fabrication, all edges of plates shall be prepared for welding and shaped to joint configuration.
- (ii) Plates shall be cut to shape and size by oxygen, arc cutting, machining or by grinding. If oxygen or arc cutting is used, all slag and detrimental discolored materials which have been molten shall be removed and the edges of plates shall be smooth, uniform and free of all loose scale and slag accumulations.

e. Curving of Plate

- (i) Plates shall be formed to the required curvature by any process that will not damage the physical properties and surfaces of the materials. Prior to curving, the plates shall be cleaned of loose mill scale to ensure that such loose mill scale is not pressed into the plates.
- (ii) Cylindrical curving shall be in the direction of mill rolling. Shaping by blows shall not be allowed. If plates are to be shaped by rolling, the joining edges of longitudinal joints will first be shaped to the proper curvature by preliminary forming.
- (iii) Templates shall be used to check the accuracy of the curving process, and flat spots along the completed joint will not be allowed. After shaping, correction to obtain proper curvature shall be by pressure, not by blows.

f. Fabrication of Portable Unit

Steel penstock, including bends and other cylindrical sections, shall be shop-fabricated to circular plate courses with no more than 2 longitudinal welds per course. The number of field girth welds should be held to a minimum, and portable penstock units shall not be less than 6 m long, except for make-up units. Each portable unit shall be fully

fabricated including all stiffeners, grout outlets, manhole, or other openings in the shell and other attachments.

g. Shop Assembly

The portable segments of the reducer pipe and bent pipes shall be temporarily trial-assembled, fitted and match-marked in the shop. Required corrections revealed by inspection shall be made prior to transportation of the segment to the final location in the Works. The reports of all shop assembly shall also be submitted to the Engineer for review.

h. Dimensional Tolerance

(i) Out of Roundness

Out of roundness of the internal surface, measured as the difference between maximum and minimum inside diameters at any cross section, shall not exceed one half of 1 percent (0.5%) of the nominal inside diameter. At final fit, the weld root and alignment tolerances can be met by jacking or other approved means.

(ii) Weld Root Opening and Groove Angle

The weld root opening at all butt joints shall be within plus or minus 3 mm and groove angle thereof shall be within plus or minus 5 degrees of the design requirements, unless otherwise approved by the Engineer.

(iii) Alignment Tolerance

Butt edges of plates at both longitudinal and circumferential joints shall not, after being welded, have an offset from each other at any point greater than 1.5 mm. Offsets on the internal surface shall be ground smoothly in order that a bevel is not greater than 1:4.

i. Marking

All sections shall be properly marked and match-marked by indicating a serial number for proper identification when erection.

j. Handling, Preparation for Transportation and Support

(i) Handling attachments or procedure shall not result in harmful bending of plates or injuries of plate surfaces.

(ii) Materials and equipment to be shipped shall be prepared in a manner satisfactory to the Engineer.

(iii) Lugs, supports, or external braces shall be welded to stiffener rings or girders, wherever possible. All temporary lugs, supports or external braces welded to the shell plates shall be fully removed after erection completed, and the welds shall be ground flush.

- (iv) All internal braces or spiders shall be removed after the concrete encasement has been completed. The welded areas shall be ground flush and repair painted.

TM-6.7 AIR VACUUM/RELEASE VALVE

The Contractor shall supply an air vacuum and air release valve to be installed at the highest point of the penstock. A separate isolation valve shall be provided to allow maintenance of assembly with the penstock in operation.

TM-6.8 PAINTING

The Contractor shall be responsible for the painting for the penstock and shall strictly comply with the specified Clause TG-14. The majority of the painting shall be done in the shop prior to shipment. Only touch-up and areas of the welds shall be done in the field.

TM-6.9 GROUT BOX

The grout box will be 100 by 100 by 50 mm and welded to the inversion of the straight sections of the penstock to allow low pressure grouting. Each box will have a threaded connection to allow grout pipe to be screwed into the box. The final number will be confirmed after detail concrete encasement design.

TM-6.10 ACCESS MANHOLE

Manhole, at least 600-mm diameter shall be provided at main valve downstream for service. The Contractor shall ensure minimum disturbance of the flow.

TM-6.11 ERECTION

The Contractor shall provide all special tools to perform all work required for the erection including transportation to the site, storage, installing, positioning and welding of previously shop-fabricated steel components.

Prior to field erection start, the Contractor shall submit detailed schedule within the limits of the project schedule requirement to include the following.

- a. Proposed description of the erection sequence to be proceeded.
- b. Method to be applied for erection such as the procedure of fit up, welding, stress relieving, testing and placing concrete.
- c. Erection and Installation Drawings and Diagrams.

The Contractor shall, to the satisfaction of the Engineer, supply all anchors, stiffeners, spiders, bracing, ties and any other attachments which will be required to maintain the shape of penstock to support them securely in place without distention or displacement during fabrication, handling, transportation, erection, alignment, welding, placing concrete and grouting work.

All metal works to be in contact with or embedded in the concrete shall be rechecked for centering and alignment of the end of the exposed pipe immediately after the concrete is placed.

TM-6.12 WELDING

a. General

In principle, the Contractor shall carry out the shop welding work following on the requirement as specified in Clause TG-12 Welding strictly. All welding shall be performed by the shielded metal arc process. The design and construction of welded joints subject to internal hydrostatic pressure shall conform to the requirements of the ASME Boiler and Pressure Vessel Code, Sections VIII and IX, Division 1, latest edition. Welding of external structural components shall conform to the requirements of AWS D1.1. Welding electrodes shall be AWS 5.1, Specifications for Mild Steel Covered Arc Welding Electrodes.

b. Welding Procedure

In principle, the Contractor shall propose the Engineer the welding procedure specifications (WPS) and procedure qualification records (PQR) as well as the welding sequence and certified reports of results of specimen tests made by the approved third party for approval prior to the commencement of any welding. After the welding procedures have been approved by the Engineer, the Contractor shall record them on the special drawings which shall thereupon become drawings of the Contract. The procedure qualification of the welding and the tests of qualification plates representing the joints shall be in accordance with the requirements of the ASME Boiler and Pressure Vessel Code, Section IX, Welding and Brazing Qualifications.

c. Qualification of Welder

All welding operators employed by the Contractor shall have passed the qualification tests for the approved welding procedure specifications (WPS) to be used in accordance with the requirements of the ASME Boiler and Pressure Vessel Code, Section IX, Welding and Brazing Qualifications. At any time, the welder will be required by the Engineer to undertake additional qualification tests to determine his ability to perform the type of work in which he is currently engaging. Any additional qualification test shall be made in the presence of the Engineer's representative. The Contractor shall furnish all test coupons and welding electrodes required for the qualification tests.

The Contractor shall submit the Engineer the certified reports of qualification tests for all welders engaged in the work. All expenses in connection with making the qualification tests shall be borne by the Contractor.

d. Welding Electrode

The welding electrode shall be of low-hydrogen optimum electrode for base metal in case of automatic and manual welding operation. Characteristics of welding electrode shall be superior to the base metal in ultimate tensile strength, yield point stress and elongation.

Electrode shall be shipped in properly weather-protected metal containers, and shall be kept in these containers as long as possible. The containers shall be opened at the location of the works, and the electrode shall be supplied to the job in small lots. Following the opening of a container and up to the time of issue, the dryness of electrode shall be maintained by placing it in a drying oven according to ASME Section II Part C. Electrode which has become wet shall be rejected and permanently identified as such.

The flux to be used for submerged arc-welding shall be maintained in dry condition. Prior to its use, it shall be placed in a drying oven according to ASME Section II Part C.

e. Cleaning Surface for Welding

Edges to be welded and plate surface extending 12 mm. from each side shall be properly cleaned to remove rust, grease, burning slag or other foreign matter detrimental to good welding results. All slag on welds shall be completely removed prior to depositing subsequent bead. Arcs for starting welding passes shall be struck only within the area to be welded. Weld spatter adhering to the shell plates shall be removed by grinding.

In the case of manual welding, the backside of all groove welded shall be wholly arc gouged or back chipped to sound and clean metal.

f. Preheating

Preheating procedures shall be as recommended ASME and shall be suitable to the plate thickness and the degrees of restraint at the welded joints. Preheating shall extend to all areas within 150 mm of where welding is to be performed.

g. Precautions against Moisture

Welding shall not be performed on wet surfaces. The welding operation areas shall be protected against inclement weather, high winds and rain. The Contractor shall supply all temporary shelters or any protection to enable maximum productivity in inclement weather.

h. Welding Defect

Welding defects listed below shall be carefully removed and corrected to assure the welding performance.

- Crack, blow-hole, slag inclusion, and insufficient depth of fusion.
- Overlap, undercut, irregular bead surface and pits.
- Insufficient throat and leg length of fillet welding

In this case, the Engineer reserves the right to reject unsatisfactory and irregular work and demand the Contractor to replace such defective work.

i. Finish of Welded Surface

Butt weld surfaces shall be ground smoothly to remove all ripples or irregularities having a degree of roughness which, in the opinion of the Engineer, may result in potential stress risers or possible masking of defects on radiography films.

j. Inspection of Weld

Radiographic and other inspection methods for weld inspection and keeping of records thereof shall conform to the requirements of the Clause TM-6.13 Tests and Inspection.

k. Welding in Thick Plate

Where thick plates will be subject to stress, special attention shall be given to the joint design. As well, the welding procedure and the inspection of thick plates and welds to avoid tearing shall be submitted for approval.

TM-6.13 TEST AND INSPECTION

a. General

All parts of the Works shall be subject to inspection and testing during fabrication, erection and on completion. All equipment required for testing shall be provided by the Contractor. The Contractor shall maintain and experienced and qualified force to control the work and to perform the testing specified, in order to maintain the verification, inspections and tests during all stages of the works. Defects shall be correctly remedied by the Contractor in order to meet the Specifications at the Contractor's expense.

b. Repair of Materials with Defect

When laminations or other defects are disclosed, the extent of such laminations or defects inspection shall be determined by the use of ultrasonic (UT) examinations of the area.

Defects in materials discovered on or after delivery from the steel manufacturer have to be removed and repaired by welding properly to meet the satisfaction of the Engineer. The repaired areas shall be re-examined by the ultrasonic (UT) examination and by one or more of the magnetic particle (MT), liquid dye-penetrant (PT) and radiographic (RT) examinations, at the direction of the Engineer.

c. Inspection of Plate and Fitting

- (i) In addition to the inspection specified, all prepared edges shall be inspected visually prior to shipment to ensure that they are free from defects, including cracks, laminations, segregation and slag inclusions.

d. Nondestructive Examination of Welded Part

All nondestructive examination shall conform to the requirements of the ASME Boiler and Pressure Vessel Code Section VIII.

All welds in bifurcation and concrete embedded penstocks weld joints shall be inspected by radiographic examination (RT) or phased array ultrasonic testing (PAUT) with 100 percent of welds.

All welds in exposed penstock shall be inspected by liquid penetrant examination (PT) or magnetic particle examination (MT) with 100 percent of root pass and cover pass of weld joints

The Contractor shall submit the Engineer full written records and results covering all welding examination conducted and describing all defects in due course.

End of Chapter

DRAFT

TECHNICAL SPECIFICATIONS
ELECTRICAL EQUIPMENT

LAMTAKONG HYDROPOWER PROJECT
TECHNICAL SPECIFICATION – ELECTRICAL EQUIPMENT

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**TE-2 HYDRO GENERATOR AND
REGULATED SYSTEM**

EQUIPMENT WORKS
ELECTRICAL EQUIPMENT - TECHNICAL SPECIFICATIONS
TE-2 HYDRO GENERATOR AND REGULATED SYSTEM

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TE-2 HYDRO GENERATOR AND REGULATED SYSTEM

The each generator shall be consisted of complete set of synchronous generators, brushless excitation (if applicable), power inverter (if applicable) and auxiliaries system such as air natural cool, bearing components, brake (if applicable), heater (if applicable), instruments, auxiliary terminal box, terminal boxes for main & neutral side, base frame, foundation bolts or dowels and accessories which have finished testing at manufacturer work shop, ready and suitable for install with turbine equipment with all major components & accessories required for trouble free and long-term operation. The contractor shall be responsible for the design, manufacturing, installation, and testing of a hydro generator with excitation or a hydro generator with a converter, ensuring trouble-free and long-term operation.

TE-2.1 RATINGS AND CHARACTERISTICS

TE-2.1.1 Hydro Generator Ratings and Technical Data

Regulated System	with	Excitation	Converter
No. of unit		1	
Type		3 Phase AC Synchronous	
Standards		IEC 60034	
Power delivered (The electricity that is produced by the generator deducted by equipment power losses and power consumed by the plant's auxiliaries during normal operating conditions at the rated net head)	kW	1,500	
Rated output @ Rated power factor	kW	Not less than 1,645	
Rated power factor	lagging	0.85	*
	leading	0.85	*
Rated voltage	kV	3.3 or 0.690	*
Voltage range about rated value, with rated generator output, speed and power factor	%	± 5	
Frequency	Hz	50	0 - 500
Efficiency at rated power output, including loss in the bearings	%	95.0	97.0
Minimum short-circuit ratio		0.7	*
Rated speed	rpm	Defined by driven turbine	
Maximum runaway speed	rpm	Defined by driven turbine	

Stator winding connection		Star	
Ambient temperature	°C	40	
Stator winding insulation		Class F	
Field winding insulation		Class F	
Temperature rise limit (stator core, stator winding, field winding)		Class B (not exceed 80°C)	
Enclosure		IP23	IP68
Type of cooling		To be defined by the Contractor	
Field winding temperature		by resistance method	
Type of bearing		Pad or sleeve type having babbit metal lining with oil lubricated	Ball bearing
Bearing temperature, by RTD	set	2 × PT100 per bearing	
Air inlet-outlet temperature, by RTD	set	2 × PT100	
Heater	set	1	
Brake	set	1	
Type of excitation		Digital (AVR) brushless excitation	Permanent magnet

* To be design by contractor

TE-2.1.2 Electrical and Mechanical Characteristic

Electrical characteristics

Unsaturated value of direct-axis reactance	X_{du}	shall be as low as possible, consistent with economic design
Unsaturated value of direct-axis transient reactance	X'_{du}	
Saturated (rated voltage) value of direct-axis sub-transient reactance	X''_d	shall be as high as possible, consistent with economic design
Minimum short-circuit ratio		Not less than 0.7
Nominal ceiling voltage of excitation system of rated load field volts	%	Not less than 150

Spare excitation capacity above nominal requirement	%	Not less than 10
Total Harmonic Distortion (THD) of line-to-line voltage, on open circuit at rated speed and voltage	%	Not greater than 5
Deviation factor of wave form, measured in percent from line-to-line on open circuit at rated voltage and frequency	%	Not greater than 5
With the generator initially at rated kVA, terminal voltage, power factor and speed, the excitation system shall be capable of changing rated field voltage to 95% of ceiling voltage for a sustained drop in generation terminal voltage of 5%	ms	To be defined by the Contractor

Mechanical characteristics

Flywheel effect (J) of rotating parts of the generator include external flywheel (if applicable) not less than		To be defined by the Contractor, as required by the Turbine manufacturer
(The price for the total flywheel shall be included in the respective item price of the generator)		
Maximum runaway speed (subject to verification by turbine manufacturer)		To be defined by the Contractor
Ratio of first bending critical speed to maximum runaway speed		not less than 1.10
Minimum duration of operation at maximum runaway speed	min	5
Direction of rotation, as viewed from turbine side		Clockwise
Maximum temperature of cooling water for oil cooling system	°C	30

TE-2.2 GENERAL DESIGN

TE-2.2.1 Type and Design Criteria

The generator shall be of the synchronous type, with the shaft directly coupled to the turbine or using a speed increaser. Provision shall be made to install and maintain the generator and accessories without powerhouse crane. Necessary lifting and set-down devices for handling with mobile crane (if applicable) shall be provided. The Bidder shall propose the procedure for

installation of the turbine and/or generator with alignment method in his Bid proposal as well as procedure of assembly and disassembly to be done during maintenance period.

The Contractor shall ensure that each generator shall meet the recommendations of IEC 60034 Standards for electrical rotating machinery and follow the Provincial Electricity Authority (PEA) Grid Connection and Operation Code to ensure compliance with the electrical network standards.

Complete information including supporting calculations regarding the maximum stresses used in the design shall be furnished to the Engineer for approval.

TE-2.3 STRUCTURAL CONSTRUCTION DETAILS

TE-2.3.1 Generator Stator

The stator frame shall consist of an assembly of welded, adequately sized steel sheet, reinforced by rigid longitudinal and transverse ribs. The frame shall be supported on soleplates furnished by the Contractor and placed on the concrete foundations. Design of stator frame shall be such that the flow of cooling air is kept undisturbed and speeds of air flow are chosen so as to prevent any undue movement of the stator frame when the generator is subject to dynamic stresses such as obtained during short circuit conditions.

The stator core shall be built up with high grade, low loss, non-aging silicon steel laminations. Each lamination shall be varnished, with an insulating varnish, on both sides, to reduce eddy current losses. Air ducts in the stator core shall be arranged for efficient, smooth and quiet flow of air, minimizing air friction losses.

Standard resistance type temperature detectors (PT100) shall be embedded in a suitable approved location of the stator core.

Number of RTD shall be design according IEC 60034, Number of RTD's spare shall equal to number of installation.

The stator windings shall be made of copper, multi-turn or single turn type, insulated with full Class "F" insulation, according to the IEC Standards.

The stator winding shall be identical for all the stator windings and shall be so impregnated with high grade insulating varnish that the insulation becomes a dense, homogeneous mass, free from air pockets. The Contractor shall make provisions to secure the winding in the slots so the horizontal sliding of any coil or bar shall be avoided.

All joints or connections shall be brazed with a suitable copper or silver brazing alloy and shall be insulated with class F insulation.

Six (6) standard resistance type temperature detectors (PT100) shall be furnished and installed in approved locations of the stator winding.

The stator winding shall be protected by differential and stator ground fault relays installed on the respective relay panels described in TE-5 Control, Monitoring and Protection System, of

these Technical Specifications. The stator winding leads shall be brought out to an approved location of the stator frame in suitable terminal box and connected to power cable (XLPE) with easy access, connection and inspection.

TE-2.3.2 Generator Rotor

The generator rotor shall be designed and constructed in accordance with the best modern practice and shall withstand safely the maximum runaway speed without exceeding the allowable unit stresses specified in TG-8.

For generator with converter type, the rotor pole shall use permanent magnet, neodymium-iron-boron (NdFeB), to create magnetic field. Contractor shall design operation to prevent permanent magnet demagnetization in any condition (strained, temperature, etc.). (if application)

The generator field winding shall be insulated with Class "F" insulation in accordance with IEC Standards, and shall be capable of withstanding all mechanical stresses imposed by the maximum runaway speed. The winding shall consist of copper strips directly wound on the poles, according to the manufacturer's standard practice and approved by the Engineer.

The natural flywheel effect (J) shall be incorporated into the generator rotating parts. The Contractor shall examine the possibility for eventual necessary additional external flywheel which may also be used for braking of the unit. The price for the total flywheel effect shall be included In Item Price for generator.

Damper windings shall be provided on the pole shoes capable of withstanding unbalanced short circuits. (Only applicable for salient pole generator)

TE-2.3.3 Generator Shaft

The generator shaft shall be made of forged, open- hearth, carbon or alloy steel, properly heat treated and shall operate safely coupled with the turbine at any speed up to and including the maximum runaway speed without detrimental distortion or vibration. The critical speed of the combined turbine and generator shaft shall be checked by the turbine's manufacturer after obtaining rotating parts drawings from the generator manufacturer.

The shaft shall be free of injurious flaws and imperfections, shall be smoothly and accurately machined all over, and shall be polished at the bearing surfaces and at accessible points for alignment checks. The amount of shaft run-out shall not exceed the tolerances recommended for generator shafts in the applicable Standards. Run-out shall be checked by rotating the finished shaft in a lathe or aligning device in the Manufacturer's shop.

TE-2.3.4 Alignment of Shaft

The alignment for the combined rotating generator shaft and turbine shaft shall be under the Contractor's responsibility. The alignment test shall be done at site.

TE-2.4 GENERATOR BEARINGS

a. The bearing can be of:

1. Pad type or sleeve type having babbitt metal lining. Oil grease lubricated or self-lubrication or forced lubrication type.
2. Anti friction ball/roller bearing, oil or grease lubricated type.

These bearings shall be guaranteed for continuous working for one hundred thousand (100,000) hours and shall be of proven design and performance.

Bearings shall be adequately insulated to prevent any harmful circulating currents. The thrust bearing shall be suitable to take axial thrust in both directions. The bearing shall be designed to withstand any damage, in case the machine is operated on runaway speed for a period of 5 minutes.

The oil used for generator bearing lubrication shall be the same as used for turbine governing system and bearing.

The temperature of the bearing metal shall not exceed the provision in Table 1 when the temperature of cooling water is 30 °C.

Table 1 Allowable temperature rise value for the hydro turbine generator bearings

Type of the bearing	Maximum allowable for alarm °C.	Maximum allowable for trip °C.
Babbitt bearing bush of thrust bearing	75	80
Babbitt bearing bush of guide bearing	70	75
Rolling bearing	95	100

b. Bearing Temperature Indication

Two (2) standard resistance type temperature detectors (PT100) shall be furnished and installed in suitable or approval locations of each bearing and shall measure bearing shell or pad temperatures as close to the lining to journal or thrust ring interface as practicable.

These shall be connected to the unit control system to give the following signals, trips and indication. Location of RTDs bearing shall be submitted for approval.

At least two (2) limit values shall be provided for each detector.

- First stage for alarm
- Second stage for trip

TE-2.5 LUBRICATION OIL SYSTEM

TE-2.5.1 Lubrication Oil Unit (if required)

Force lubrication type bearing shall be compact design for installation, which is also responsible for supply of required quantity, flow rate of bearing oil at required temperature to the bearings, on continuous working basis.

- a. The unit consists essentially of:
 - Oil tank
 - Oil pan
 - Filter units, filter blocking device
 - Piping
 - Two (2) gear pumps, one for normal operation and the other for stand-by
 - Integrated cooling unit
 - Isolating valves, control valves
 - Heating and dehumidifiers (if require)
 - Level indicator - switches, temperature sensors, pressure switches or oil flow failure switch and shall have the following provisions:
 - Automatic change-over from normal to the stand-by oil pump.
 - Protection devices.
 - Terminal box for power supply, intermediate terminal of the sensors.

The oil used for generator bearing lubrication shall be the same as used for turbine governing system and bearing.

TE-2.5.2 Cooling System

The cooling unit shall be provided to satisfy the requirement under TM-5 of this Technical specification.

TE-2.6 GENERATOR AUXILIARY

TE-2.6.1 Generator Cooling System

The generator shall be self-ventilated, natural air cooling system and the protection will be IP23. The temperature sensors (PT100) shall be located in suitable location, one (1) for air inlet and one (1) for air outlet.

In case of converter type, IP68 protection rating for operating in submersible condition.

The exhaust warm air will be guided by air ducts (if required) coupled to a special flange on the generator up to the exit of the power house. The ducts and the associated accessories shall also be included in the scope of supply.

The contractor shall independently design the type of cooling system then it shall be submitted to EGAT for consideration and approve.

TE-2.6.2 Generator Braking System (if applicable)

Generator braking system shall be of the proven manufacturer's standard design. Hydraulic brakes shall be provided for mechanical braking of unit, which are normally applied at approximately 30 % of the unit's rated speed. Limit switches are provided on brakes for "Brake ON" & "Brake OFF" annunciation / indication.

TE-2.7 GENERATOR EXCITATION SYSTEM (if applicable)

Each generator shall be provided with an excitation system of brushless type and regulating system for continuous stable operation of the generator under manual excitation control or automatic voltage regulator control. The equipment shall conform to IEEE Standard No.421 "IEEE Standard Criteria and Definitions for Excitation Systems for Synchronous Machines" and the latest applicable IEEE, NEMA or IEC Standards, and shall meet all the performance requirements and withstand all the tests described herein. The excitation system shall include an AC exciter with rotating diodes bridges mounted on the generator shaft. The three phase power supply from the AC exciter shall be rectified by the rotating diodes bridges for the generator field winding. The diodes bridges shall be protected by a de-excitation resistor connected in parallel. All diodes modules shall be interchangeable and shall be removed easily. The Automatic Voltage Regulator (AVR) shall control the generator voltage by regulating the field current automatically and shall be installed in the Excitation Board.

The excitation system shall be capable of supplying continuous stable load rating and adequate field excitation, with sufficient spare power rectifier capacity as specified herein, for all operating conditions within specified ratings and operating ranges of the generator as stipulated in these Technical Specifications, including, but not limited to, when the generator is :

- a. Delivering rated kVA at rated voltage or at a voltage of 5 percent above or 5 percent below rated voltage and at rated or other power factor and frequency.
- b. Operating continuously under-excited or over-excited at zero or other power factor at the proposed respective outputs by the Contractor.

The excitation system shall also be capable of maintaining adequate generator field voltage, avoiding generator instability or shutdown, during a three-phase short circuit at the 22 kV side of the generator transformer, which is described in TE-5 of these Technical Specifications, for a time duration of 1.2 seconds, or that time required for the generator back-up protection described in TE-5 of these Technical Specifications, to clear the short-circuit, whichever is the greater.

The excitation system shall be complete including all necessary devices for protection, control, indication and alarm annunciation and shall have the following features and facilities:

- a. Auto-manual voltage regulation transfer switch (regulator transfer)
- b. Manual control voltage adjusting device (base voltage adjuster)
- c. AC voltage adjuster for AVR

- d. Protection against AVR failure as follows, but not limited to :
 - 1. Over/under-excitation limiter (combination with over/under voltage)
 - 2. No load, On-load and Volts per Hertz limiter
- e. An alarm annunciation system, to annunciate alarms the following, but not limited to:
 - 1. Diodes rotating bridges faults
 - 2. AC exciter faults
 - 3. AVR faults
 - 4. Excitation transformer faults. (if applicable)
 - 5. Under and over-excitation limiter operation
 - 6. All automatic protective trip conditions
- f. AVR shall be suitable for operating with an automatic start/stop control including automatic synchronization system as specified in TE-5.

TE-2.7.1 Excitation Transformers (if applicable)

For brushless exciter, the AC power for operation of the AVR shall be supplied by three phases, indoor, cast coil, copper conductor, dry type transformers with a minimum of class F insulation, self-cooled, 80°C temperature rise over 40°C ambient air temperature, connected to the generator terminals.

Alternatively, the transformer may be omitted if the AVR system can be powered from an alternative power source.

TE-2.7.2 Static Excitation System (Not applicable)

TE-2.7.3 Automatic Voltage Regulator and Control Equipment

- a. The AVR shall be microprocessor-based design for generator voltage control application only. The Contractor shall furnish automatic voltage regulating equipment, mounted in sheet metal cubicles as described herein. The regulating system shall provide for automatic control to adjust and maintain excitation system output DC voltage from 50% percent of rated voltage to that required for generator maximum continuous rating. Other components shall be added to the excitation system to obtain exciter performance in order to maintain the generator terminal voltage within accuracy limits specified herein. Provision shall be made for rapid field de-excitation whenever the unit lockout relay (86E) operate.
- b. The automatic voltage regulator shall continuously respond rapidly enough to correct any change in generator voltage and maintain the generator terminal voltage under steady state load conditions, within plus or minus 0.5 percent, without hunting, for any excitation value within the operating range specified. Under steady state conditions with the generator open-circuited, the regulator shall not permit the terminal voltage of the generator to vary more than 10 percent of its setting from 105 percent of rated speed up to an over speed of 50 percent.

The equipment shall include devices for improving the damping of system electromechanical oscillations, complete with speed deviation detection or reactive drop compensation, suitable booster for permanent control during steady load conditions as approved by the Engineer. The Engineer will supply necessary power system data as required for the above purpose.

- c. The AVR shall be comprised of One (1) communication port for interface with turbine control board (PLC) and One (1) communication port for interface with programming tool.
- d. The Contractor shall furnish all control switches, transfer switches and indicating instruments necessary for operation or test, and such control, protective and relaying devices as are considered necessary for coordination with the excitation system equipment specified herein in order to obtain a complete excitation and control system for the generator.
- e. Current and potential transformers, required by the excitation system supplied, shall be furnished by the Contractor as specified herein.

TE-2.7.4 Excitation Board

- a. The excitation and voltage regulator equipment shall be mounted in sheet metal enclosed cubicles to form an excitation board, with full length doors located to permit easy access to the equipment. Louvers necessary for adequate ventilation, and designed to prevent the entrance of rodents, shall be provided.
- b. Auxiliary ac and dc supplies for all devices shall be as follows :
 - 1. Control power for all control, indication and annunciation purposes shall be 48 volts dc.
 - 2. Auxiliary ac power shall be three-phase, 400 volts, 50 Hz, or single-phase 230 volts, 50 Hz as required.

TE-2.8 POWER CONVERTER SYSTEM (if applicable)

The inverter shall convert the produced variable AC voltages of the generator into usable AC energy and coordinate the efficient and safe operation of the whole system. The inverter proposed for this project shall be on grid-connected type with enclosure.

In order to utilize the output effectively the inverter proposed for this project shall have the following feature;

- Automatic start / stop function
- High converting efficiency
- Low stand-by loss

- Low loss at the low load

The following grid support function shall be provided;

- Active power control
- Reactive power control
- Power factor control
- Low voltage ride through function with reactive power injection

In the case that an accident of the grid and the inverter, the interconnection with the grid shall be interrupted, and the inverter shall stop safely.

The inverter shall be stable against the usual change of the voltage and frequency of the grid.

The inverter shall be protected against thermal overload, over-current and over-voltage, manufactured by ISO certified manufacturer and approved by EGAT.

The inverter system shall meet Electromagnetic Compatibility (EMC) norms IEC/EN 61000.

Details	Technical Requirements
<u>Converter system</u>	
• Installation	In building structure or container building
• Type of inverter	Generator Connected
• Rated power output per unit	$\geq 1,895$ kVA
• Converter systems efficiency	$> 96.5\%$
<u>Converter system input voltage</u>	
• Maximum allowable voltage	*
• Frequency	*
<u>Converter system output voltage</u>	
• Voltage	*
• Current	*
• Maximum current	*
• Phase	3

- Driven Output Power factor 0.9 leading to 0.9 lagging
- Total Harmonic Distortion (current) < 3 %

Cooling System

- Max coolant input temperature * 30 °C
- Coolant flow rate *
- Coolant *

Power Consumption (stand-by)

(*)

Degree of protection

≥ IP20

Data Communication port

Yes

Communication with Controller

Yes

Environment Condition

- Ambient temperature 0 - 45°C
- Humidity 0-95 % (Non-condensing)

Operation Manual

Yes

Instruction Manual

Yes

Service Manual

Yes

Recommended Spare Parts (with list)

Included

* To be defined by the Contractor

The contractor shall submit documentation confirming that the inverter is registered on the Provincial Electricity Authority's (PEA) approved list.

TE-2.9 CURRENT TRANSFORMERS

Current transformers, bushing or ring type, rated at the generator rated voltage having basic impulse insulation level of not less than the specified in the IEC 61869-2 Standards with IEC Accuracy Classification 5P20 for relaying, 0.5 for excitation and 0.5 for metering, shall be furnished and mounted inside appropriate cubicles.

The current transformers shall be capable of withstanding for one (1) second the thermal and mechanical stresses resulting from the maximum short circuit current of the generator. Current transformers shall be fully tested in the shop, including low frequency dielectric test, ratio, and phase angle error tests. The Contractor shall furnish to the Engineer certified copies of the test results made in accordance with the Manufacturer's standard practice of characteristics adequate for metering and relaying as approved by the Engineer.

Each current transformer used for generator differential relay (87G) shall have the same technical characteristics.

TE-2.10 POTENTIAL TRANSFORMERS (NOT APPLICABLE)

TE-2.11 NEUTRAL CUBICLE (If applicable)

The Contractor shall furnish a metal-enclosed neutral cubicle with access doors, which shall comprise the following equipment:

- a. Single-phase distribution transformer shall be, indoor, dry type, Generator terminal voltage /220 or 120 volts. The primary winding shall be connected between the generator neutral and the ground bus, and the secondary winding connected to a loading resistor. The transformer and resistor shall be designed such that the maximum line-to-ground fault current does not exceed 15 amperes, and shall be capable of carrying the maximum line-to-ground fault current for ten (10) seconds. A single pole disconnect switches shall be provided at primary winding of the neutral transformers as on Single Line Diagram drawing.
- b. Cable terminal compartment, complete with cable supports and terminals, suitable for cable entry through the top of the cubicle.
- c. Wiring, and 600 volt terminal blocks for ground protection relaying circuits.

An alternate method of grounding the generator neutral through a resistor will also be acceptable instead of the above specified method of grounding through a distribution transformer.

This second method shall comprise the following equipment in lieu of the specified under subparagraph 2.11

- a. The Generator resistor shall be connected between the generator neutral bus and the ground bus.
- b. The resistor shall be designed so that the maximum line-to-ground fault current does not exceed 15 Amperes, and be capable of carrying such maximum line-to-ground fault current for at least ten (10) seconds.
- c. A current or voltage transformer (according to the Manufacturer's practice) for the supply of the stator earth fault protection relay.

Neutral grounding shall be in accordance with IEEE Std C62.92. Calculation sheets shall be submitted for approval.

The transformer shall be tested at the factory to determine its characteristics in accordance with the applicable IEC Standards.

TE-2.12 SPACE HEATERS

The Contractor shall furnish an adequate number of thermostatically controlled electric space heaters within the generator air housing to prevent condensation of moisture when the unit is shut down.

TE-2.13 INSTRUMENTS AND DEVICES

The Contractor shall furnish the following instruments and devices with each generator. Devices provided for alarm and trip purpose shall be adjustable at having least two (2) electrically independent contacts for each function with current breaking capacity of 3 amperes. Contacts shall be of the circuit closing type for alarm or trip functions. The resistance temperature detectors (RTDs) shall be of PT 100 ohms types at 0°C embedded in the stator (cores & windings) which shall be connected to the unit control system and shall be used to give the following signals, trips and indications at the turbine control board. Location of RTDs shall be in accordance with IEC 60034 and submitted for approval.

At least two (2) limit values shall be provided for each detector.

- First stage for alarm
- Second stage for trip

The visual local oil level indicators (O.L.) shall have three (3) contacts giving.

- Low level an alarm
- Low level a trip
- High level an alarm

The above instruments shall be installed in the following locations.

- a. Generator stator winding
 - One (1) RTD per phase for signaling and tripping
 - One (1) RTD per phase as spares
- b. Generator stator core
 - One (1) RTD per phase for signaling and tripping
 - One (1) RTD per phase as spare

TE-2.14 INTERCONNECTION FOR DEVICES AND ACCESSORIES

Interconnection leads within the generator and air housing including leads for space heaters, control, under speed and over speed switches, resistance temperature detectors, temperature relays, and other accessories, shall be furnished and installed in rigid, galvanized steel conduits. Leads shall be arranged, as far as practicable, to make removal unnecessary when the generator is dismantled. Leads which extend for interconnection to devices beyond the generator shall terminate in terminal cabinet (s) with hinged doors complete with 600 volt terminal blocks at approved locations. All necessary interconnecting piping, tubing and fittings between sensing

elements, orifices, and indicating instruments, relays and gages specified herein to be furnished by the Contractor, shall be furnished and installed for the lengths required.

TE-2.15 TURBINE AND GOVERNOR ACCESSORIES

The turbine supplier will furnish an approved speed signal device and overspeed switches for supplying the governor circuits. The generator supplier shall cooperate with the turbine supplier in mounting these devices and shall furnish and install the necessary wiring in concealed conduits to terminal boxes at approved locations.

TE-2.16 INSULATION AGAINST STRAY CURRENTS

Each generator shall be adequately insulated against any possible stray currents set up by the field of the generator causing injury to the generator, turbine or speed increaser bearings. The thrust bearing bracket shall, in addition, be insulated against stray currents.

TE-2.17 FACTORY ASSEMBLY, INSPECTION AND TESTS

No generator part or complete generator shall be shipped until each part has been inspected and approved, or inspection thereof has been expressly waived by the Engineer in writing, all in accordance with the Conditions of the Contract.

The winding of completely assembled stator and rotor shall be tested according to IEC 60034-1 Standards. Bidder shall propose the testing method of the above test with his Bid.

Design or type test for determination of the all machine parameters and characteristics (reactance, time constants) may be submitted, otherwise the Contractor shall perform factory and/or field tests to determine these values. Some parameter could be determined by calculation, the Contractor shall submit for approval.

Unless otherwise specified, each generator shall be performed routine test according to IEC 60034.

The following Performance Tests on generator shall be done at factory, **except Power Delivery Guarantee Test shall be done at Site.**

- a. Efficiency test by method of segregated losses acc. to IEC 60034-2, which shall include the determination of I^2R losses in armature and field windings, and all losses in friction and windage, core, and stray load. The excitation system losses will be included as a part of the total losses in the determination of the efficiency.
- b. Output test to determine that the measured output of the generator is not less than the generator output as specified in clause 2.1.1 when operating at rated voltage, and at a voltage 5 percent above or 5 percent below rated voltage, and at rated frequency and power factor for the temperature rises.

The above Performance Tests shall be applied for one (1) generator for each model.

For generator with excitation system shall be completely assembled at the Manufacturer's shop and subject to a standard commercial test, including, but not be limited to, the following :

- a. Dielectric tests in accordance with IEC Standards for excitation system.
- b. Auxiliary wiring tests at 2000 volts, 50 Hz, for one (1) minute.
- c. Excitation system standard performance tests by simulator.

All other electrical parts, including other equipment, devices and instruments, shall be tested separately in accordance with applicable IEC Standards and shall be subject to inspection and test procedures according to Contract stipulations.

For generator with converter systems shall be test as follow IEC standard.

TE-2.18 FIELD TESTS

Each generator shall be completely tested after installation is completed, in accordance with the provisions of this Section in order to determine whether the Contractor guarantees and the requirements of these Technical Specifications have been fulfilled. The tests shall be made, except as herein definitely specified, in accordance with applicable requirements of IEC Standards.

The Contractor shall perform **Power Delivery Guarantee Test** to determine that the measured output of the generator at the Power Quality Meter (PQM), which is installed next to the generator transformer, is not less than the guaranteed power delivered when operating at rated voltage, and at a voltage 5 percent above or 5 percent below rated voltage, and at rated frequency for the temperature rises, as specified in TE-2.1.1. Power delivered is defined as the electricity produced by the generator, deducted by equipment power losses and power consumed by the plant's auxiliaries during normal operating conditions at the rated net head.

The waiver of any test shall not relieve the Contractor of his responsibility to meet fully the requirements of these Technical Specifications. All test equipment and material including instrument transformers, cables and conductor materials and test instruments including special instruments such as multi-channel ultraviolet recorders or oscillographs, and test engineers, shall be furnished by the Contractor at his own expense and shall remain the Contractor's property after completion of the tests.

The Contractor shall furnish a complete detailed test program and description of field procedures to be followed for the tests to the Engineer for approval not later than three (3) months prior to the date on which the generator is scheduled for testing. Certified copies of reports for all tests shall be supplied to the Engineer for approval.

Each generator shall be subject to the following tests after complete erection:

- a. Insulation resistance test of armature and field windings and all devices including small wiring and check of insulation against shaft currents.

- b. Dielectric tests of armature and field winding. The armature windings of each phase shall be given a dielectric test in accordance with IEC Standards, with other windings grounded.
- c. Winding resistance, inductance and capacitance measurement tests of armature and field windings.
- d. No-load saturation test.
- e. Short circuit saturation test.
- f. Heat run test to determine the maximum temperature rise of the various parts of the generator when operating continuously at rated output with an air cooling entering the generator regulated to 40°C. Load for the tests will be provided at rated voltage and frequency.
- g. Tests to determine the quantities and temperatures of inlet and outlet cooling water (if applicable) for the generator bearings and for surface air coolers, (if applicable) when the unit is operating continuously at rated output.
- h. Test to determine the wave form deviation factor. Oscillograms shall be taken of the wave form of the terminal voltage of each phase of the stator winding when the unit is operating at no-load at rated voltage and frequency. This test will be made between 2 phases according to IEC-Standards.
- i. Overspeed test for two (2) minutes.
- j. Alignment of the unit shafts by mechanical rotation and balancing of the unit .
- k. Zero power factor saturation test .
- l. Operation test and adjustment of the excitation system to demonstrate compliance with all operation and performance requirements of these Technical Specifications. These shall include, but shall not be limited to, the following :
 - 1. Excitation system duties :
 - (i) Manual and automatic control setting range.
 - (ii) Inductive and capacitive continuous loading capability.
 - (iii) Temperature rise **(if applicable, only for static excitation valid)**.
 - (iv) Full-load rejection capability.
 - (v) Overspeed duty.
 - (vi) Parallel operation with other generator.

2. Accuracy of the excitation control system during changes of :
 - (i) Load.
 - (ii) Ambient temperature.
 - (iii) Supply voltage frequency and magnitude.
 - (iv) Reference voltage frequency and magnitude.
3. Ceiling voltage.
4. Voltage of response.
5. Stability of the excitation control system during :
 - (i) Inductive and capacitive loading limits.
 - (ii) Steady state operation.
 - (iii) Transient conditions.
- 6 Heat run to determine the maximum temperature rise after continuous output at rated full-current and reduced voltage.
- m. Test to determine the time for unit brakes to stop the machine safely from 30 percent speed to zero speed with the turbine guide vanes fully closed and with the unit circuit breaker open.
- n. Trial run test for 24 hours or follow PEA code.

TE-2.19 RATING PLATES AND NAME PLATES

Permanent stainless steel rating plates in the English language shall be mounted on the generator and excitation equipment, in suitable locations showing :

- a. Manufacturer's name and address
- b. Serial number and date of manufacture
- c. Generator and rated kVA, voltage, power factor, and speed

Name plates in the English language for all switches, relays, meters and other devices in the cubicles shall be provided as described in TG of these Technical Specifications.

TE-2.20 WRENCHES, SPECIAL TOOLS AND SPECIAL DEVICES

The Contractor shall supply, special tools, slings, and other special devices that may be required for assembling or dismantling any part of each generator or auxiliary equipment. These shall include a special lifting device for erection.

(No special wrenches are required for the maintenance, dismantling or assembly of these generators. Only standard tools are necessary.)

TE-2.21 REQUIRED PARTS

The Contractor shall furnish the following parts for which unit prices shall be included in the List of Materials and Prices :

	Excitation	Converter
a. One (1) set of carbon brush and brush holder with accessories (if applicable)	Yes	-
b. One (1) complete set of rotating diodes bridge for excitation system	Yes	-
c. One (1) set of overvoltage protection equipment for excitation system (if applicable)	Yes	
c. One (1) complete set of electronic printed cards of each type used in the regulated system.	Yes	Yes
d. One (1) resistance temperature detector for bearings of each type.	Yes	Yes
f. Permanent magnet for replacement N pole	-	Yes
g. Permanent magnet for replacement S pole	-	Yes
h. One (1) complete set of bearings (metal or ball/roller)	-	Yes

One complete set of parts described above is defined as the total number of the parts required for one unit of the equipment specified in this Chapter. Each type of parts stands for the different parts in sizes, pressure or current ratings, functions, etc.

End of Chapter

TE-3 MEDIUM VOLTAGE POWER CABLES

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TE-3 MEDIUM VOLTAGE POWER CABLES

TE-3.1 DESIGN, CONSTRUCTION, RATING AND CHARACTERISTIC

The MV power cables, indoor or outdoor type, shall be provided for suitable connection between the Equipment as shown on the Single Line Diagram drawing. Insulated MV power cables shall be capable of meeting all requirements specified herein and all applicable requirements of IEC 60502 Standards. The outdoor cable shall be underground installed.

The above-mentioned power cables shall be of single core type according to IEC 60502. If other Standards are approved by the Engineer, they shall be applied for the cable construction. However, the power cables shall also meet the following specific requirements:

- | | | |
|------|------------------------|---|
| (a.) | Size | Suitable cross section for the service they are intended to perform (Not less than 35 mm ²) |
| (b.) | Conductor material | Stranded copper |
| (c.) | Insulation | XLPE |
| (d.) | Circuit identification | Phase A red
Phase B yellow
Phase C blue |

Cables shall have a rodent protection by mean of brass tape or steel wires underneath the outer jacket. The cables shall be marked on their overall sheath according to IEC Standards. Splicing of the single conductor medium voltage cables shall not be allowed.

The Contractor shall submit to the Engineer for approval, calculations for load and short circuit carrying capacity of the power cables. Current carrying capacity will be determined by using the reduction factors from IEC 60287 Standard in accordance to the cable arrangement installation.

Such cables shall also meet the minimum requirements listed below:

(a.)	Rated voltage	3.6/6 kV	18/30kV
(b.)	Rated frequency	50 Hz	50 Hz
(c.)	Continuous current	In accordance with the rated current of the generators and transformers	
(d.)	Minimum short circuit current duration	1 s.	1 s.
(e.)	Maximum continuous ambient Temperature	Indoor : 40°C	
		Outdoor : 45°C	
(f.)	Temperature rise of conductors during continuous operation above ambient	90°C	
(g.)	Temperature rise of conductors during short circuit conditions above ambient temperature	250°C	
(h.)	Short circuit current	12.5kA	25 kA

TE-3.2 REQUIREMENTS FOR THE CABLE SEALING ENDS

All cable sealing ends shall be suitable for the respective single core power cables mentioned herein. Generator and transformer will have their own terminal box. No additional cable boxes are provided.

The cable sealing ends shall be designed for the proper termination of the cable outer sheath and its copper wire screen (when applicable).

The Contractor shall submit to the Engineer for detailed pamphlets and design test certificates for the above cable sealing ends.

TE-3.3 FACTORY ASSEMBLY, INSPECTION AND TESTS**TE-3.3.1 Power Cables**

The insulated power cables shall be completely constructed and fabricated in the factory and subject to tests in accordance with the IEC 60502 Standards. All factory tests shall be conducted by and at the expense of the Contractor. Such tests shall include all tests on samples applicable to the particular type of cable as well as the electrical tests on the entire lengths set forth in said Standards.

The Contractor may submit to the Engineer for approval design test certificates instead of executing such tests.

TE-3.3.2 Cable Sealing Ends

The Contractor shall submit all design test certificates which are specified in IEC for cable sealing ends of each type.

TE-3.4 FIELD TESTS

The power cables shall be tested after installation according to IEC 60230 Impulse Tests on Cables and their Accessories and IEC 60811 Common Test Methods for Insulating and Sheathing Materials of Electrical Cables Standards.

TE-3.5 SPECIAL TOOLS AND DEVICES

The Contractor shall furnish special tools and devices required for installation of cable.

TE-3.6 REQUIRED PARTS (NOT APPLICABLE)

End of Chapter

TE-4 GENERATOR TRANSFORMER

EQUIPMENT WORKS
ELECTRICAL EQUIPMENT – TECHNICAL SPECIFICATIONS
TE-4 GENERATOR TRANSFORMER

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TE-4 GENERATOR TRANSFORMER

TE-4.1 GENERAL

The Generator Transformer shall be three phases, two winding, outdoor, hermetically sealed oil-immersed, ONAN with off-load tap changer. The Generator Transformer shall be designed to carry on all taps rated full-load continuously and simultaneously in the primary and secondary windings at a voltage of 5 percent above the rated secondary voltage without exceeding the specified temperature rise.

The Generator Transformer shall be use for step up power from Generator with 3.3 kV or selected voltage to 22 kV. The HV side shall be provided with lightning arrester. Number and size of the cable shall be in accordance with TE-3 MV Power Cable and TE-11 Insulated Cable and Fire Barriers.

Each transformer shall be equipped, with closed cable terminal boxes, weather proof, with cable connections for the high-voltage and low voltage bushings with cable entries, or with plug-in connections for the high-voltage connection.

A rating plate and a connection plate shall be stainless steel attached to each transformer in such position as to be clearly visible to a person operating the tap changer. Rating plate marking shall comply with respective IEC Standard and shall be in the English language.

Valves shall be globe type.

The Generator transformer, equipment, materials and devices furnished under these specifications shall conform to IEC 60076 Standard or IEEE standard C57.12.00 latest revision

TE-4.2 RATING AND CHARACTERISTIC**TE-4.2.1 Rating**

Generator transformer shall have the following characteristics:

a.	Number of units		1
b.	Type		Outdoor, Hermetically sealed oil- immersed
c.	Phase		3
d.	Type of Cooling		ONAN
e.	Continuous rating capacity on all taps. The rating of the generator transformer will be finally defined on the rating of each generator	kVA	* (At least 2,000)
f.	Rated frequency	Hz	50
g.	Rated Voltage - HV Side - LV Side	kV kV	22 *
h.	Insulation level (BIL) of windings/power frequency (Dry-1 min) - HV Side - LV Side - Neutral	kV peak/rms kV peak/rms kV peak/rms	125/50 * *
i.	Insulation level (BIL) of bushings/power frequency (Dry-1 min) - HV Side - LV Side - Neutral	kV peak/rms kV peak/rms kV peak/rms	125/50 * *
j.	Connection of winding		YNd1, Solidly Grounded
k.	Ambient temperature	°C	45
l.	Winding temperature rise at maximum continuous rating capacity - Average - Hottest Spot	°C °C	55 68
m.	Temperature rise of insulating oil (Top oil)	°C	50
n.	Off-load tap changer, on HV side		± 2 x 2.5%
o.	Positive sequence impedance at rated voltage	%	6
p.	Audible sound level	dB(A)	<61
q.	Bushing current transformer - HV Side - LV Side - Neutral		N/A N/A *

* To be determined by Contractor

TE-4.2.2 Transformer Losses

Each transformer shall be designed and constructed so that no-load and load losses are as low as possible. Maximum loss values shall be as follows:

- No load loss, not exceed 2.7 kW
- Load losses, not exceed 22.7 kW (at 75°C)

TE-4.3 DETAILED REQUIREMENTS

The transformers shall be equipped with the following:

- a. Windings shall be copper
- b. The transformer tank shall be double welded complete with
 - a. Oil drain valves
 - b. Filter valve
 - c. Oil sampling devices bottom of the tank
 - d. Pressure relief device
 - e. Winding temperature indicator with adjustable trip and alarm contacts.
 - f. Oil level gauge magnetic type, with low and high oil level alarm contacts.
 - g. Dial type temperature indicator with adjustable trip and alarm contacts for oil.
 - h. All necessary lugs and shackles, pulling eyes, etc.
 - i. Two grounding terminals

Bushings shall meet the requirements of latest respective IEC standard. Bushings of same voltage shall be interchangeable between units. Wet process porcelain shall be used in bushings and shall be homogeneous and free from cavities or other defects. Glazing shall be uniform in color and free from blisters or burns. Bushings shall have puncture strength greater than the dry flashover value.

All devices for alarm and trip initiation shall be provided with two (2) ungrounded, circuit closing, electrically independent contacts, suitable for 48 VDC. Alarm and Trip contact shall be independently adjustable. Alarm and Trip signals shall be transferred to the Control and Monitoring System. The transformer can be monitored from control room.

The insulating oil shall meet all requirements of ASTM Standard (ASTM D3487 and D1275 which corrosive sulfur factor limit is 1A or 1B) and shall contain oxidation inhibitor content 0.3% maximum by mass. The transformer shall be furnished with sufficient quantity of oil for filling each tank, radiator, and bushings to the proper level. Oil shall be a refined petroleum product meeting the requirements when tested in accordance with IEC 60296 Standards. Certified copies of test reports shall be furnished for all oil shipped direct from the refinery or from the factory. Oil shall be sampled and tested in the field before energizing the transformer.

TE-4.4 FACTORY ASSEMBLY, INSPECTION AND TESTS

TE-4.4.1 General

The Contractor shall be responsible for conducting factory tests for all equipment. EGAT and/or EGAT Inspector Representative reserve the right to witness equipment and/or components performing factory tests.

Each transformer shall be completely assembled and tested in accordance with the latest version of IEC 60076 at the factory. No part shall be shipped until it has been inspected and approved in writing, all in accordance with the General Conditions of the Contract.

All tests specified herein, including repeated tests performed on rejected units after modification or repair, shall be made at the Contractor's expense to prove their compliance with these Technical Specifications.

The Contractor shall submit test procedures for all tests not less than 60 days before performing the actual tests and submit the test report.

TE-4.4.2 Routine Test

The following tests shall be made on each transformer.

- a. Measurement of each winding resistance
- b. Voltage ration at all taps
- c. Polarity and phase relation tests
- d. Measurement of short-circuit impedance and load loss
- e. Measurement of no-load loss and current
- f. Leak test for 24 hours
- g. Check of the ratio and polarity of built-in current transformer
- h. Check of core and frame insulation for liquid immersed transformers with core or frame insulation
- i. Efficiency. (25%, 50%, 75%, 100% rated load)
- j. DGA (Dissolved gas analysis)
- k. Functional tests on measuring and protection devices

TE-4.4.3 Type and Special Tests (FAT)

The following tests shall be made on the transformer.

- a. Temperature rise tests
- b. Dielectric type tests
- c. Sound level test
- d. Lightning impulse test on all line and neutral terminals

TE-4.5 SPECIAL TOOLS AND DEVICES

Transformers shall be so designed that as far as practicable, no special tools for installation and servicing will be required.

TE-4.6 REQUIRED PARTS (not applicable)

End of Chapter

TE-4A STATION SERVICE TRANSFORMER

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TE-4A STATION SERVICE TRANSFORMER

TE-4A.1 GENERAL

The Station Service Transformer shall be three phases, two winding, outdoor, hermetically sealed oil-immersed, ONAN with off-load tap changer.

The Station Service Transformer shall be designed to carry on all taps rated full-load continuously and simultaneously in the primary and secondary windings at a voltage of 5 percent above the rated secondary voltage without exceeding the specified temperature rise.

The Station Service Transformer shall be use to supply power to auxiliary system. The HV side shall connected to a load brake with fuse as specified in TE- 7.4.3. Number and size of the cable shall be in accordance with TE-3 MV Power Cable and TE-11 Insulated Cable and Fire Barriers.

Switch operating handles shall be key interlocked with the station service low-voltage main circuit breaker of AC auxiliary switchboard to prevent closing or opening of the disconnect switches when the breaker is closed. The load side of switches shall be grounded when in the open position.

A rating plate and a connection plate shall be stainless steel attached to each transformer in such position as to be clearly visible to a person operating the tap changer. Rating plate marking shall comply with respective IEC Standard and shall be in the English language.

Valves shall be globe type.

The Station Service transformer, equipment, materials and devices furnished under these specifications shall conform to IEC 60076 Standard.

TE-4A.2 RATING AND CHARACTERISTIC**TE-4A.2.1 Rating**

Generator transformer shall have the following characteristics:

a.	Number of units		1
b.	Type		Outdoor, Hermetically sealed oil-immersed
c.	Phase		3
d.	Type of Cooling		ONAN
e.	Continuous rating capacity on all taps. The rating of the generator transformer will be finally defined on the rating of each generator	kVA	* (At least 120 kVA, including 20% spare capacity)
f.	Rated frequency	Hz	50
g.	Rated Voltage - HV Side - LV Side	kV kV	22 400/230
h.	Insulation level (BIL) of windings/power frequency (Dry-1 min) - HV Side - LV Side	kV peak/rms kV peak/rms	125/50 *
i.	Connection of winding		Dyd11, Solidly Grounded
j.	Ambient temperature	°C	45
k.	Winding temperature rise at maximum continuous rating capacity - Average - Hottest Spot	°C °C	55 68
l.	Temperature rise of insulating oil (Top oil)	°C	50
m.	Off-load tap changer, on HV side		± 2 x 2.5%
n.	Positive sequence impedance at rated voltage	%	*
o.	Audible sound level	dB(A)	<57

* To be determined by Contractor

TE-4A.3 DETAILED REQUIREMENTS

The transformers shall be equipped with the following:

- a. Windings shall be copper
- b. The transformer tank shall be double welded complete with
 - a. Oil drain valves
 - b. Filter valve
 - c. Oil sampling devices at bottom of the tank
 - d. Pressure relief device
 - e. Oil level gauge magnetic type, with low and high oil level alarm contacts.
 - f. Dial type temperature indicator with adjustable trip and alarm contacts for oil.
 - g. All necessary lugs and shackles, pulling eyes, etc.
 - h. Two grounding terminals

One current transformer shall be supplied at LV neutral ground fault protection.

All devices for alarm and trip initiation shall be provided with two (2) ungrounded, circuit closing, electrically independent contacts, suitable for 48 VDC. Alarm and Trip contact shall be independently adjustable. Alarm and Trip signals shall be transferred to the Control and Monitoring System. The transformer can be monitored from control room.

The insulating oil shall meet all requirements of ASTM Standard (ASTM D3487 and D1275 which corrosive sulfur factor limit is 1A or 1B) and shall contain oxidation inhibitor content 0.3% maximum by mass. The transformer shall be furnished with sufficient quantity of oil for filling each tank, radiator, and bushings to the proper level. Oil shall be a refined petroleum product meeting the requirements when tested in accordance with IEC 60296 Standards. Certified copies of test reports shall be furnished for all oil shipped direct from the refinery or from the factory. Oil shall be sampled and tested in the field before energizing the transformer.

TE-4A.4 FACTORY ASSEMBLY, INSPECTION AND TESTS

TE-4A.4.1 General

The Contractor shall be responsible for conducting factory tests for all equipment. EGAT and/or EGAT Inspector Representative reserve the right to witness equipment and/or components performing factory tests.

Each transformer shall be completely assembled and tested in accordance with the latest version of IEC 60076 at the factory. No part shall be shipped until it has been inspected and approved in writing, all in accordance with the General Conditions of the Contract.

All tests specified herein, including repeated tests performed on rejected units after modification or repair, shall be made at the Contractor's expense to prove their compliance with these Technical Specifications.

The Contractor shall submit test procedures for all tests not less than 60 days before performing the actual tests and submit the test report.

TE-4A.4.2 Routine Test

The following tests shall be made on each transformer.

- a. Measurement of each winding resistance
- b. Voltage ration at all taps
- c. Polarity and phase relation tests
- d. Measurement of short-circuit impedance and load loss
- e. Measurement of no-load loss and current
- f. Leak test for 24 hours
- g. Check of the ratio and polarity of built-in current transformer
- h. Check of core and frame insulation for liquid immersed transformers with core or frame insulation
- i. Efficiency. (25%, 50%, 75%, 100% rated load)
- j. DGA (Dissolved gas analysis)
- k. Functional tests on measuring and protection devices

TE-4A.4.3 Type and Special Tests

The following tests shall be made on each transformer.

- a. Temperature rise tests
- b. Dielectric type tests
- c. Sound level test
- d. Lightning impulse test on all line and neutral terminals

TE-4A.5 SPECIAL TOOLS AND DEVICES

Transformers shall be so designed that as far as practicable, no special tools for installation and servicing will be required.

TE-4A.6 REQUIRED PARTS (not applicable)

End of Chapter

**TE-5 CONTROL, MONITORING AND
PROTECTION SYSTEM**

EQUIPMENT WORKS**ELECTRICAL EQUIPMENT – TECHNICAL SPECIFICATIONS****TE-5 CONTROL, MONITORING AND PROTECTION SYSTEM****TABLE OF CONTENTS**

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TE-5 CONTROL, MONITORING AND PROTECTION SYSTEM

TE-5.1 UNIT CONTROL & DIGITAL GOVERNOR, MONITORING AND PROTECTION SYSTEM

TE-5.1.1 Scope

The Contractor shall design, supply, procure, delivery to Site, install, conduct the commissioning test of the unit control & digital governor, monitoring and protection system for the turbine-generator unit, regulated system (if any), transformer, switchgear and station auxiliaries including all interfaces and associated equipment, cabling, wiring and termination.

The general technical requirements for the control, monitoring and protection system shall be automatic control and supervision of one (1) turbine-generator unit, inlet valve, transformers, switchgear and station auxiliaries. The normal control level shall be operated at Operator Control Station (OCS) in the control room and in the case of maintenance or commissioning or testing, the control level shall be done by Maintenance/Engineering laptop or at Unit Control Board (Local graphic control panel) or Local Equipment. The system architecture shall be designed to support remote control, updating, editing and/or configuring the system from an external location (Off-site Control).

Open Platform Communication (OPC) server/client with licenses including OPC Data Access (DA), OPC Historical Data Access (HAD) or it shall be OPC UA with AE licenses The OPC Server shall be also provided for on-line streaming of operating data and monitoring from the external location (Off-site Control)

For variable speed concept (if applicable) turbine-generator unit, power inverter, switchgear and other equipment shall design for suitable with variable frequency operation.

The control system shall comprise a number of programmable logical controllers (PLC) of unit control & digital governor system, regulated system (if any), digital protective relay and synchronizing system. This PLC shall be connected to the man-machine interface by via of data communication cable. The metering and instrument equipment system shall be provided the information for operator including annunciation system.

The unit operation for this plant shall be automatic mode. A typical automatic mode shall be a programming control sequence stored in the PLC. The control functions shall be included supervising and monitoring the machine conditions, recording the sequence of events, alarm and fault events, providing integration of historical trending display, bar chart display and guidance messages.

The programming sequence shall be manual, step-by-step and fully-automatically as shown on below figure.

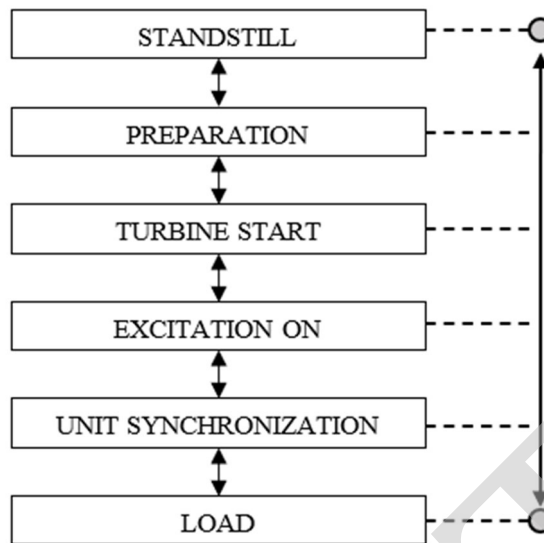


Figure-1. The control sequence for hydro generator with excitation

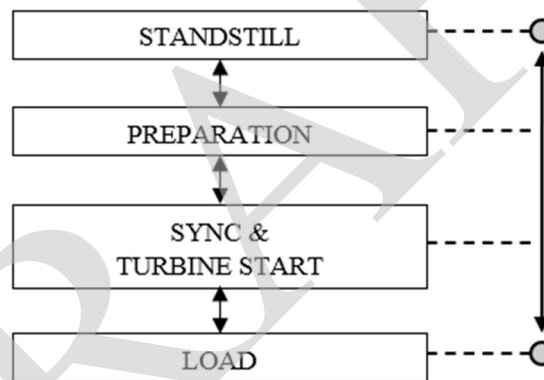


Figure-1A. The control sequence for hydro generator with converter

The control equipment for this power plant shall be comprised of the following equipment.

Operator Control Station (OCS), including licensed software for control and operation of the unit (with 2 monitors)	set	1
OCS - Historical, including licensed software (with 1 monitor)	set	1
Remote OCS, including licensed software for Off-Site Control (with 1 monitor) include software mapping	set	1
Maintenance/Engineering laptop, including licensed software tool for engineering work, such as modified configuration, adding the I/O point and perform commissioning and testing the unit control function	set	1

OPC server/client with OPC DA, HAD licenses (or OPC UA and AE).	set	1
<p>PLC of unit control & turbine governing system, including licensed software, as Unit Control Boards (UCB)</p> <ul style="list-style-type: none"> - Central processing unit (CPU) - Local graphic control panel on UCB (Touch screen) - Communication port for communication with kV control - Communication port for communication with Regulation (Excitation or Converter) system (if applicable) - Communication port for communication with Synchronization unit (if applicable) - Communication port for communication with Protection system (if applicable) - Process I/O to interface with others equipment to perform unit control function - Interfacing port for a laptop computer as specified herein <p>The turbine governing (digital governor) shall be connected with either communication port of UCB or the router</p>	lot	1
Automatic synchronization unit including synchro scope completed with accessories	set	1
Manual synchronization including synchro scope	set	1
Digital protective relay system, licensed including software for Maintenance/Engineering laptop	set	1
Routers with sufficient ports to provide Local Area Network (LAN) and routing function to enable EGAT to remote operating the power plant. The routers shall provide adequate features for cyber security for remote access and operation via internet.	set	2
Metering, instruments and annunciation display unit including transducer	lot	1
Periphery equipment such as LED monitor, printer, operator desk and chair, etc.	lot	1

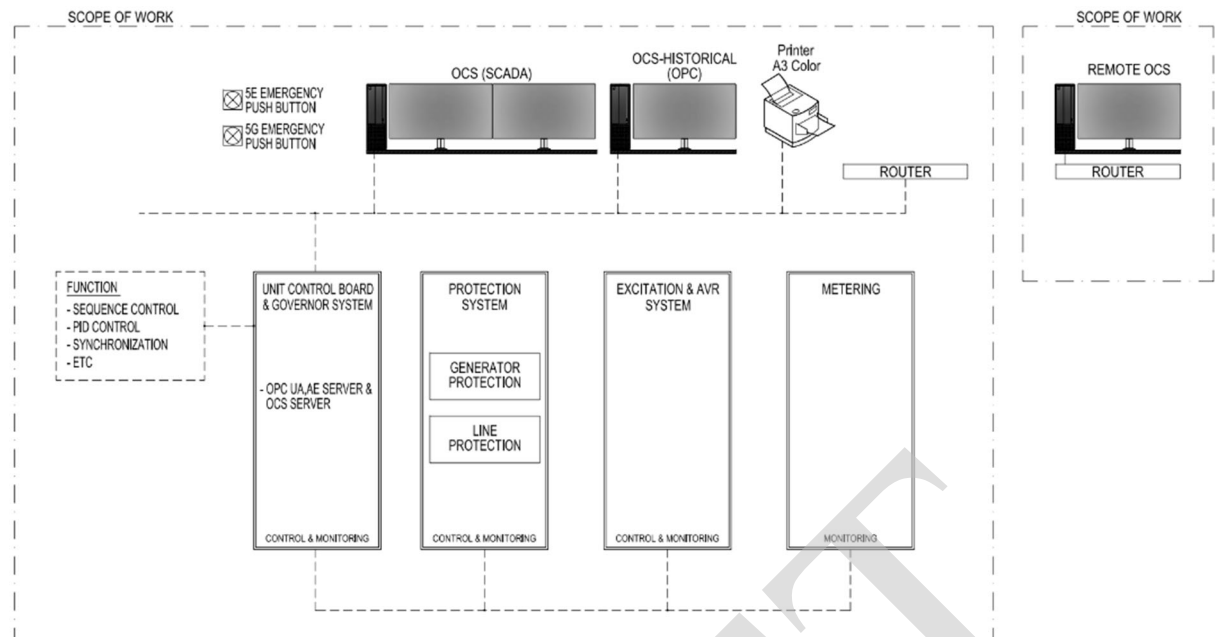


Figure-2 Control System Configuration for hydro generator with excitation

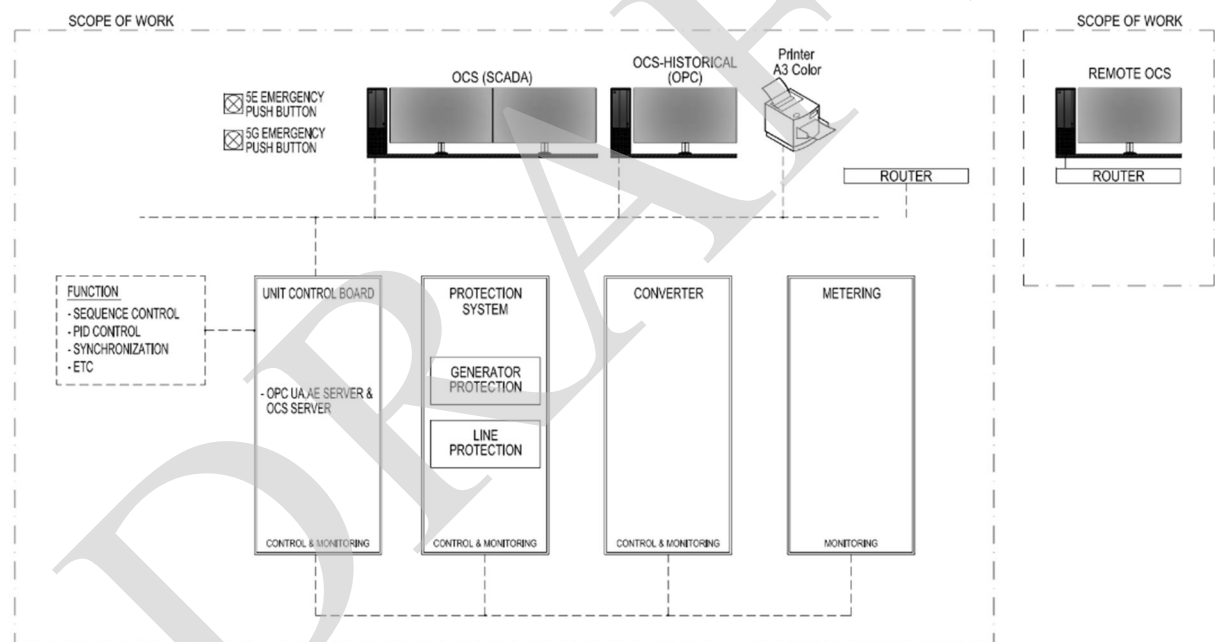


Figure-2A Control System Configuration for hydro generator with converter

TE-5.1.2 Submittals

The Contractor shall submit for review and approval by the Engineer, the following documents:

- Description and functions of the unit control & turbine governing (digital governor), monitoring and protection system and all associated equipment

- All design documents and drawings including equipment sizing calculations, relay coordination study, relay settings, system block diagrams, layout, schematics, and wiring diagrams
- Logic flow charts or descriptions for unit control sequences.
- Control system input and output lists
- Database (Tag) and Alarm list
- Format of predefined reports
- Protective trip matrix
- Specification and catalogue of all instrument and control equipment
- Instrument list
- Instrument installation drawing
- Instrument location drawing
- Graphic display for operator control station and HMI

All documents shall be in English language and submitted with electronic files.

TE-5.2 SYSTEM DESCRIPTION

TE-5.2.1 Design Philosophy

The principle automatic control, monitoring and protection system of the power plant shall be consisting of, turbine governing(s), inlet valves (s) (if applicable), generator(s), power inverter, switchgear, transformer, station service equipment and plant auxiliaries. The control shall be initiated at operator control station (OCS) for start/stop unit and can be done at Unit Control Board by via of Maintenance/Engineering laptop or Local graphic control panel. The operator shall be able to set generator output (Load setting), perform the load ramping and raise/low control. The protective trips shall be alarmed and logged. Pre and post-trip waveform shall be recorded and shall be retrieval and print out by operator. The requirement for the project viability through the use of simple and cost-effective systems and solutions has been carried through in the intent of the control system. The control, monitoring and protection system shall use time-proven design and widely available equipment and components to provide the utmost reliability. Variable speed design philosophy shall be provided for Hydro Generator with Converter. Routers with protecting and switching features, including the remote OCS shall be provided, but the internet system and external wiring to a remote location shall not be included.

Each system shall be designed to have high reliability and availability and shall be simple to operate and maintain. The failure of any equipment or the loss of power supply to equipment shall not jeopardize the plant and shall initiate an alarm.

The plant control shall be designed basically for compact small hydropower as guided in

- IEEE Std. 1020 Guide for Control of Small Hydroelectric Power Plants
- IEEE Std. 1249 Guide for Computer-Based Control for Hydroelectric Power Plant Automation
- IEC Std. 61362 Guide to specification of hydraulic turbine control systems.
- IEC Std. 61131-3 Software programming of Controller unit in Function Block Diagram

The turbine governing shall be of digital type (Digital Governor) with PID structure and modular design having a record of satisfactory and reliable service and at least as specified herein. Independent adjustable stabilizing control circuits shall be included in the control system to allow the unit to operate with an adequate margin of stability under all steady state and transient load conditions. The turbine governing system shall operate with a high degree of reliability, freedom of drift and negligible dead-band.

After all process application programs are written to the controller memory, each controller shall have free memory capacities more than 40% of all their capacities and CPU idle time shall be more than 40% of all CPU time. The Unit Control & Turbine Governing System shall also provide on-line self-diagnostics for quick analysis of system problem areas. The PLC shall be designed, in case of hardware or software failure, the capability to continue plant operation and transfer to manual control over the plant unit without upset and with adequate operator interfacing to continue operation for an extended period of time, shall be retained. However, the Bidder shall point out the differences in Bid.

TE-5.2.2 Unit Control & Turbine Governing System (UCS)

The general requirements for the Unit Control & Turbine Governing System shall be a decentralized, hierarchical structure capable of being physically distributed to various plant control equipment. The control system shall permit data acquisition and control functions to be performed and capable to monitor and protect at all equipment. The scope of supply specified in TE-5.1.1.

TE-5.2.2.1 Unit Control Boards (UCB)

The Programmable Logic Controller (PLC) as Unit Control Boards shall be programmed to control sequencing of unit, turbine governing, inlet valve, generator, kV control, electrical and mechanical plant auxiliaries, station service system and switchgear equipment. PLC shall be at least well-proven 32-bit processor design with wide range of I/O modules accepting discrete, analog and RTD inputs and shall have external memory card for data and parameter storage. The PLC shall provide on-board self-diagnostics, with on-board LED indicators defining processor controller status. The status shall also be indicated on the operator work station. The software of PLC and related equipment e.g. HMI touch screen shall be supplied from PLC's manufacturer. All PLC shall be OPC Complaint. As a minimum, the process controller shall support the following attributes:

- Analog loop shall be processed at operator tunable rate down to 10 times per second
- Binary loop shall be processed at operator tunable rate down to 10 times per second
- A full range of preconfigured algorithms that can be used to implement control strategies
- The Programming Language shall be IEC 61131-3 that capable to
 - being configured in ladder logic
 - executing higher level programming languages such as BASIC, C
 - executing operator-defined functions not included in the standard function
 - executing any combination of the above functions, i.e., standard algorithms, ladder, higher level programming languages, etc.

- Capable of peer-to-peer communication with every other module in the system
- Storing control configurations in on-board non-volatile memory

Configurations protection shall be nonvolatile random-access memory capable of retaining configuration information.

The electronic components used in the modules shall be of the highest quality, having a heavy-duty design; this requirement applies particularly to capacitors.

On-line Configuration (Not Applicable)

Maximum Processing Time

The processing time of the particular controllers shall be dedicated to the requirement of the controlled technological process and shall be in accordance with the following three categories, with maximum processing time not exceeding the specified limits:

- 50 ms for quick-acting process, e.g. electrical processing system
- 150 ms for normal sequential controls, e.g. pump control or valve actuator control
- 250 ms for modulating control

The above processing times include input operation, logic or function processing and output operation.

I/O Module

The I/O modules shall be able to support process signals from various types of sensors and contact devices without requiring external or auxiliary signal conditioning devices. The I/O modules shall include the following features:

- signal isolation
- signal conditioning including linearization, scaling to engineering units, a minimum of 12 bits analog to digital (A/D), and a minimum of 10 bits digital to analog (D/A) conversion
- Detection of the quality and presence of input signals (e.g. open thermocouple detection). The quality of each input point shall be determined and classified as either goods, questionable, substituted or bad. When bad, the value shall have bad quality indication
- Surge, over current and reverse polarity protection
- Card failure detection. Each I/O card within the system shall be monitored for proper operation. The system shall alarm indicating the card failure, and the system shall take appropriate safety action, e.g., transfer to manual, etc.
- Individual input shall be fused or feature current limiting. If fuses are provided, a common alarm contact for the fuse failure shall be provided

Standard input and output signal types shall include the following:

- Analog input: 4 to 20 mA, +/-10V or Pt100 with individual A/D conversion
- Analog output: 4 to 20 mA, +/-10V Capable of driving 600 standard or up to 750 ohms total loop resistance at 4-20 mA

- Binary input: capable of receiving 24 V dc, 48 V dc
- Binary output: Isolated contact rated at least 2 A dc @ 24 V dc, 0.5 A dc @ 48 V dc and user selectable as normally open or normally closed
- RTD input: Capable of receiving 100 ohms platinum

The Unit Control Board is a unit control function and shall be included functions of turbine governing, synchronizing, electrical protection, control sequencing, kV control and load set point.

TE-5.2.2.2 Turbine Governing

The turbine governing shall be of digital type (Digital Governor) with PID structure and modular design having a record of satisfactory and reliable service and at least as specified herein. Independent adjustable stabilizing control circuits shall be included in the control system to allow the unit to operate with an adequate margin of stability under all steady state and transient load conditions. The turbine governing system shall operate with a high degree of reliability, freedom of drift and negligible dead-band.

The unit will be connected to the 22kV network of the Provincial Electricity Authority (PEA). For normal operation it is not required the governor to make a frequency regulation and the governor shall be equipped with a circuit manually adjusted which shall energize the governor action in a frequency range between 49.5 Hz and 50.5 Hz.

The design closing time of the guide vane shall be as defined in the guaranteed characteristics so that the speed rise of the turbine and the maximum pressure rise in the penstock shall not exceed the value defined in the guaranteed characteristics.

The governor shall be capable of controlling with stability, the speed of the turbine when operated at rated speed and no-load, or when operating at rated speed at all power outputs, including maximum output of the turbine.

The Contractor shall design and provide the governor oil system having capacity and reliability as required by the governor operating condition as specified in TM-2.

TE-5.2.2.3 Voltage Control (kV Control)

To maintain the high-side voltage in the designated range, the voltage control function shall be provided to regulate it automatically. Contractor shall provide this function, design and supply graphic display on Operator Control Station (OCS) as well as on Local Graphic Control which both use to monitor and send signal to operate the control as “kV Mode”. There shall be 2 modes provided to approach the voltage control;

5.2.2.3.1 Local high side voltage control

The contractor shall provide this function to control the high-side voltage of the generator transformer locally. In case of fail communication or any acceptable failure, voice communication or some standard communication shall be provided.

5.2.2.3.2 Local high side reactive power control

The contractor shall provide this function to control the high-side reactive power of the generator transformer locally. In case of fail communication or any acceptable failure, voice communication or some standard communication shall be provided.

The contractor shall conform to the designated parameters to achieve the voltage control. The following parameters shall be prepared and adjusted according to PEA electrical system condition (PEA Interconnection Code 2016 or latest version): Reference voltage, Voltage Dead Band and Power Factor.

TE-5.2.2.4 Inlet valve control (If applicable)

The inlet valve shall be provided with hydraulic pressure from the governor oil system. A separate accumulator tank shall be provided complete with all electric and hydraulic control required for the complete operation of the inlet valve.

The Contractor shall design and provide the inlet valve control, including sensing and indicating devices as required by the hydraulic oil system, operating and functional requirements as specified in TM-4.

TE-5.2.2.5 Irrigation valve control

The irrigation valves shall be provided with electric valve as specified in TM-5.

The Contractor shall design and supply graphic display on Operator Control Station (OCS) which use to monitor and send signal to operate the irrigation valves as specified in TM-5, which located in the irrigation control house when operator select switch function on the local control cubicle (at the irrigation control house) as "AUTO" mode.

The graphic display, use to monitor and operate the Irrigation valves shall be the same software version and same manufacturer with Plant control software. Moreover, the Irrigation valves can also operate and monitor at local control cubicle.

TE-5.2.2.6 Operator Control Station (OCS)

The operator control station and remote OCS shall be at least 32-bit multiprocessor provide an interface to the Unit Control Board and equipped with monitoring and control through graphic displays. These displays shall effectively have shown equipment status and process state. Dynamic data and static data graphic elements shall be able to be combined on any display. Control and monitoring system real-time data shall be prepared for OPC DA interface and supported by the OPC DA server. OPC tunneling for secure data transfer and overcome of DCOM security breach shall be provided and configured for OPC DA server and client connection.

The operator control station shall be provided at least the following requirements:

Processor	:	≥ Intel® Xeon® E-2378 Processor ≥2.60 GHz or Higher
Physical memory	:	8 GB DDR4 SDRAM at 2400 50% of installed memory
Graphic card	:	MID Range 3D graphic card with DVI/DP interface

Hard Drive	:	2 x 1TB, 7200 RPM Hard Drive, SATA 6 Gbps with RAID 1 configuration
Monitor	:	24 inch WLED 1920 x 1200, Adjustable Stand, DVI / DP interface / HDMI
Network interface	:	2 x Ethernet interface card
Software	:	Latest Microsoft Windows operating system, Antivirus Software, Personal firewall software and other software required to complete OIS function
Power Supply	:	Redundant power supply unit, 230 Vac, each min 350 Watts with PFC
Thermal design	:	Minimum 3 fans, ATX chassis with tool less opening
Other	:	USB Optical mouse , standard Keyboard with Thai keys
Security	:	Removable media boot control, Serial, parallel and USB interface control, power-on password, setup password, and Memory change alert (through BIOS, in windows environment & on management consoles) Internal smart cover lock & sensor for securing internal components; such as, USB port cover. Kensington slot on chassis for physically securing the chassis

The laptop computer as the engineering station shall be at least Intel Core i7 12 series processor/Equivalent; minimum 8 GB RAM, 512 GB Solid State Drive, 1 TB Hard drive, External DVD writer, and color LCD display, communication module for access into Unit Control Board and station bus and shall be also provided the following requirements:

Computer interfacing	:	RS- 422, RJ-45 and RS-232C with software and facilities supports
Operating ambient temperature	:	up to 50 °C
Operating humidity	:	10 - 90% RH
Vibration resistance	:	IEC61131-2
Degree of Protection	:	IEC60529 IP66
Input power supply voltage	:	100-240 V AC (+10%)

TE-5.2.2.7 Interfaces

The communication between the OCSs and the UCB shall be communicated over at least Gigabit Ethernet (IEEE802.3z). The communication between the UCB shall be directly interface to Intelligent Electronic Devices (IEDs) such as the excitation system, protective relaying system, synchronization unit and digital power meters via of MODBUS. Signal status, alarm, continuous and control signals shall be relayed through the LAN between the control systems and IEDs.

TE-5.2.2.8 Remote Process Input/Output

Remote process input/output including cabinet shall be used for collecting the signal in case of the equipment is too far from the PLC by via of standard industrial communication.

TE-5.2.2.9 Remote Control (Off-Site Control)

The OPC server shall enable database transmission to the remote control (remote OCS). The operation as well as logic configuration shall be available remotely without OCS's disturb. The remote OCS shall be provided and tested at site for the EGAT's implementation in the future.

TE-5.2.2.10 Local Graphic Control

A local graphical control which install on PLC cubicle shall have feature for operation and maintenance purpose. The Local Graphical Control Panel shall have the specifications as follows:

Display	: 14 inches HMI touch panel, as minimum
Resolution	: 1024 x 720 Pixel, 256 colors, as minimum
Keypad	: membrane keypad type and touchscreen
Main display window	: The following importance parts shall always be visible <ul style="list-style-type: none"> - system status - reference adjuster raise and lower - actual and set point value - panel control - available screens - operation level
Operating	: The following features shall be provided <ul style="list-style-type: none"> - command buttons for controlling the system - selectable all signals in the software
Parameter	: The following feature shall be provided <ul style="list-style-type: none"> - access to all parameters - parameter description in English - parameter selection
Trending	: The following feature shall be provided <ul style="list-style-type: none"> - at least six (6) free selectable signals - trending with long time recording up to 24 hours - saving and reloading of trending
Data logger	: auto save and reset function
Fault logger	: dynamic indication of the actual faults and alarms
Environment	: IP65 or equivalent
Memory	: up to 8Mb, flash ROM for OS and data storage
Interfacing	: RS- 422 and RS-232C including software and facilities
Supports	
Operating ambient	: up to 50 °C
Operating humidity	: 10 - 90% RH
Vibration resistance	: IEC61131-2
Degree of Protection	: IEC60529 IP66
Power supply	100-240 V AC ($\pm 10\%$) and 48 or 24 V DC ($\pm 10\%$)

The OCS and local graphical control panel of each unit shall display the information as follows.

- Unit ready
- Control in automatic or manual mode

- CPU failure
- Communication failure
- Power supply failure
- Unit speed
- Active power (MW)
- Reactive power (MVar)
- Generator voltage
- Generator current
- Field voltage
- Field current
- Unit status (operation step and mode)
- Permanent speed droop, indication and adjustment
- Regulator parameter (proportional, integral, derivative), for on-line/off-line settings
- Watchdog status
- Speed dead band
- Start position guide vane limiter (in both adjustable and automatic compensated by water head level)
- Guide vane position
- Guide vane limit
- Runner blade position
- Load setter
- Speed setter
- Loading rates, megawatt per second
- DI/DO/AI/AO point value or status
- Protection point status
- kV Control

The following controls shall be provided on the local graphical control panel of each main unit.

- Regulator parameter (proportional, integral, derivative), for on-line/off-line settings
- Guide vane limiter (raise/lower)
- Speed/load setter (raise/lower)
- Guide vane position (raise/lower)
- Runner blade position (raise/lower) (if required)
- Loading rates, megawatt per second (raise/lower)

TE-5.2.3 Local Area Network (LAN) and Interfaces

The local area network shall be at least CAT5 and hub linking the operator control station and Unit Control Board (PLC). The communication software and licensed shall be included.

TE-5.2.4 Master Clock System (not applicable)

TE-5.2.5 Protective Relaying System

The protective relaying system shall be an integrated system of IEDs consisting of multi-functional digital relays, high-speed lockout relays, shutdown relays, and auxiliary relays mounted in one or more cubicles.

TE-5.2.5.1 Protective Relays

The protective relays shall be microprocessor-based using digital signal processing technology and software to provide the protection functions, outputs, alarms, fault recording and communication capabilities. Each relay shall be provided with a communication port for communication with the control system. A communication port shall also be provided for a laptop computer.

The settings for the relay functions shall be programmed via laptop computer using software supplied by the manufacturer and uploaded into the relays.

The digital relaying system shall be communicated with PLC and technical specification specified in TE-5.4.

TE-5.2.5.2 Lockout Relays

Lockout relays shall be high speed half-cycle type, solenoid operated, mechanically latched, with pistol grip manual reset handle. Output contacts shall be rated for 2 A at 48 V DC. Sufficient contacts shall be supplied for all stated functions.

TE-5.2.5.3 Auxiliary Relays

Auxiliary relays shall be rail-mounted socket type with sealed case and coils and contacts rated for 48 V DC.

TE-5.2.5.4 Protection Circuits

Relays and protection circuits shall be rated for 48 V DC and shall be supplied from separate dedicated fused DC circuits. Loss of supply relays shall monitor the supply and shall alarm the control system upon loss of DC. All VTs and CTs circuits shall be supplied with test switches for isolation and tests.

TE-5.2.5.5 Metering

All metering shall be a digital type power meter with Ethernet communication for directly interface to PLC and can be recording information and shall be shown on operator control station and shall be print out the information when required. Meters shall have backlit LCD screen for display of quantities and phase vectors, and controls for selection of measured and calculated quantities. Meters used for monitoring distribution line electrical quantities shall be of revenue metering accuracy class. The meters shall include software to allow the control system to perform:

- Waveform capture
- Waveform record harmonic analysis

- Total harmonic distortion (THD) analysis
- Typical history and real time trends

TE-5.2.5.6 Revenue Meter

The Contractor shall provide the electronic type revenue meters from manufacturers that had supplied records for previous EGAT powerplant or approved by EGAT with panel according to the Single Line Diagram having the following requirements:

- 3 phases 3 wires/ 3 phase 4 wires capable measure import/export of electrical values such as kWh, kVarh, kW and kVar;
- Accuracy class: For active energy, it shall not less than 0.2S according to IEC standard 62053-22, and 0.5S for reactive energy referring to IEC standard 62053-24;
- Internal memory; for not less than 45 days to record the electrical data (energy/demand) for every 15 minutes;
- Software installed for use of TOU (Time of Use Tariff) and TOD (Time of Day Tariff) capable to read information remotely through Automatic Metering Reading (AMR);
- Modem and converter RS485/RS232 or others approved by EGAT;
- One (1) set of test switch.

TE-5.2.6 Unit Synchronization

For Hydro Generator with Excitation

A digital synchronizer shall be supplied to permit manual and automatic synchronizing of the unit (s) output to the grid. The system shall include interfaces with the governor and AVR for speed and voltage matching.

The synchronization unit shall include the following:

- Synchronization indicating lights
- Synchronizer
- Synchronization check relay

For Hydro Generator with Converter

Power converter shall operate as manual and automatic synchronizing of the unit (s) output to the grid. The system shall be smooth synchronizing before machine in operation. Synchronization status shall be indicated.

TE-5.2.7 Remote Terminal Unit (not applicable)

TE-5.2.8 Nameplates

Nameplates shall be in accordance with the specifications outlined in TG-13 Nameplate and Marking.

TE-5.2.9 Accumulated Flow Recorder Software

An accumulated flow recorder software shall be provided in order to record accumulated flow which required for power generation of each generating unit. Turbine flow shall be calculated from the following formula :-

$$Q = P / (9.81 \times H_n \times \eta_T \times \eta_G)$$

Where

Q	=	Turbine flow in cms.
P	=	Plant output in kW.
H _n	=	Turbine net head in m.
η _T	=	Turbine efficiency at the actual head H _n and actual turbine output, reading directly from guaranteed hill-curve of the turbine
η _G	=	Generator efficiency under output P, reading directly from guaranteed generator efficiency curve.

The software for calculator of the accumulated flow shall be submitted to the Engineer for approval. The Contractor shall provide digital indicators of the calculated accumulated flow and turbine flow on the Unit Control Board as well as on the screen of the operator console.

TE-5.3 CONTROL SYSTEM FUNCTIONS

TE-5.3.1 Control Modes

Control mode, consist of automatic control and manual control mode, shall be selected via OCS and Local graphic control panel on UCB graphic control panel.

While the UCB is in local, operation, transfer of local and remote operation shall not conflict and keep the existing step of operation.

In case of communication network failure, control system test, maintenance and operation or emergency operation the unit shall be controlled at Unit control panel of each equipment.

TE-5.3.2 Local Mode

In the Local mode, all plant equipment shall operate from the Unit Control Board through:

1. Local automatic control at graphic control panel
2. Local manual control at each equipment i.e. excitation cubicle, local cubicle, etc.

TE-5.3.3 Remote Control Mode (from OCS)

While in the Remote Control, an operator shall be able to select one of the following Control Sequence from the operator control station:

a. Manual mode

The unit and associated equipment shall be manually controlled through the operator control station.

b. Step by step mode

The operator shall be able to “step” through each step of the Auto sequences by initiating each step.

c. Auto mode

All unit control sequences shall be carried out automatically once initiated by an operator.

TE-5.3.4 Remote Control Mode (from Remote OCS)

The control sequence of Remote OCS shall be Manual mode, Step by step mode and Auto mode as TE-5.3.3. While remote OCS is operating from a distance (EGAT property) with priority and network security. Field test shall be done by the contractor during commissioning period. The external wiring shall be provided by EGAT.

TE-5.3.5 Control Sequences

The UCS shall be capable of executing any control sequences selected and initiated by an operator in all control modes except the manual mode. Once a sequence is initiated, the UCS shall check that all permissive associated with the selected sequence have been satisfied prior to starting the control sequence.

TE-5.3.5.1 Start and Synchronize Sequences

For Hydro Generator with Excitation

a. Start to SNL sequence

The unit shall be started from a standstill with excitation applied at 95% of rated speed and shall remain at Speed No Load (SNL) where it awaits a Synchronize sequence command.

b. Synchronize sequence

The system shall initiate the auto-synchronizer function to match voltage and frequency of the running unit to the EGAT grid. Once voltages and frequencies are matched, the control system shall close the generator breaker and load the unit to rated output.

For Hydro Generator with Converter

a. Start and Synchronize sequence

The unit shall be pre charged converter to control voltage and synchronize to grid after that start generator converter and start turbine simultaneously then unit shall operate in level or power control mode to generate energy to Grid by controlling guide vane opening.

TE-5.3.5.2 Shutdown Sequences

For Hydro Generator with Excitation

a. Normal shutdown sequence (5B)

The sequence is normally initiated by the operator or control system to shutdown the unit. An incomplete start sequence shall also initiate it. The unit shall be first unloaded and excitation reduced to maintain terminal voltage. The generator breaker shall then open followed by the governor closing the guide vanes. Brakes shall be applied at approximately 30% of rated speed determined by the generator supplier. The creep detector shall be deployed once the unit came to a stop. There is no overspeed of the unit.

b. Emergency shutdown sequence (5E)

The emergency shutdown shall be initiated a number of ways via:

- A red emergency pushbutton on the approved location of the powerhouse control room
- The PLC output module when the normal shutdown sequence is incomplete

The lockout shutdown relays 86E shall be energized to shutdown the unit.

For Hydro Generator with Converter

a. Normal shutdown sequence (5B)

The sequence is normally initiated by the operator or control system to shutdown the unit. An incomplete start sequence shall also initiate it. The unit shall be first reduced power to minimum load and shut down converter. Fully close the guide vane and wait until unit stop.

b. Emergency shutdown sequence (5E)

The emergency shutdown shall be initiated a number of ways via:

- A red emergency pushbutton on the approved location of the powerhouse control room
- The PLC output module when the normal shutdown sequence is incomplete

The lockout shutdown relays 86E shall be energized to shutdown the unit.

TE-5.3.5.3 Protective Shutdown

Protective shutdown of the unit is described in the protection system section and shall be performed by lockout (86) relays initiated by the protective relaying system through hard-wired circuits. The UCS shall initiate the shutdown sequence 5B to ensure proper shutdown of the unit.

TE-5.3.5.4 Incomplete Sequence

Any sequence that is not complete within a set time shall cause the UCS to trigger a sequence incomplete alarm specific to that sequence followed by a normal shutdown sequence to ensure that the first sequence is aborted and the unit is returned to the shutdown state. When the normal shutdown sequence failed, the UCS shall trip the emergency shutdown relay.

TE-5.3.6 Status-alarming

The Unit Control System shall include a status-alarm annunciation system to display all unit and equipment status and alarms at both Unit Control Boards and OCS.

TE-5.3.6.1 Audible Signals and Messages

The UCS alarm system shall generate audible tones to direct operator's attention to the latest alarm. The tones for alarms shall be followed by spoken words briefly describing the nature of the alarm and repeated every minute until acknowledged. Alarm messages can be suppressed when the powerhouse is unmanned.

TE-5.3.6.2 Alarm Acknowledgement

The system shall allow acknowledgement of alarms or groups of alarms from the operator control station keyboard or mouse. The acknowledgement shall silent the audible alarm messages but the alarms shall remain active until reset.

TE-5.3.6.3 Alarm Logging

All status, alarms, acknowledgements and resets shall be logged in the operator control station with date and time stamped.

TE-5.3.6.4 Alarm Blocking

The system shall allow blocking of selected alarms or selected groups of alarms. Alarms blocked or unblocked shall be recorded as an alarm in the summary.

TE-5.3.6.5 Status-alarm Summaries

The alarm system shall display on the operator control station summaries of status-alarms with time and date stamps. The operator shall be able to page through the overall alarm summary as any time. The summary page shall show:

- A running summary of the status-alarms with the latest entry appearing on the top of the page.

- A summary of active, acknowledged, unacknowledged, and blocked alarms.

TE-5.3.6.6 Status-alarm Indications

Color for the status-alarm lines in the summaries shall be as below

Description	Text color	Background color
Status	White	Black
Alarm- active	White	Red
Alarm - acknowledged	Red	Black
Alarm - blocked	Yellow	Black

TE-5.3.6.7 Status-alarm List

The Contractor shall provide status-alarms and display of measured quantities for all equipment including, but not be limited to, those shown in Appendix as an example.

TE-5.3.6.8 Trending

The operator control station shall be capable of simultaneously trending up to 6 parameters received by the control system for any defined time period. The operator shall be able to pan across and zoom into sections of interest. The trend shall display predefined traces or can be configured to display any acquired parameters or data.

TE-5.3.6.9 Reports

The system shall be capable of displaying and printing the following minimal set of reports:

- Alarm summary – acknowledged and unacknowledged alarms with time and date stamps.
- Summary of measured and accumulated quantities by day, week, month or year.
- Pre-Post Trip Logs shall contain two set of data, pre-trip and post-trip data, with a specified trigger event such as turbine trip. The log shall collect the value of pre-selected process variables of analog, digital and calculated data for **10 minutes** before and after the trigger event trig. The capability shall be **10 logs, 10 trigger conditions** and shall consist of up to **20 digital points** values. Data shall be collected at the rate of **1 seconds** or better. It shall be possible to obtain a post trip analysis log on demand by simulate the trigger event from the operator station. Each log shall be able to collect all data from the second trigger while information from a first trigger is being printed. The system shall store on mass memory the pre-post trip log from the last generating unit trips. The trigger point and unit MW prior to when the trip occurred shall be shown on the heading of the report.
- Sequence of events logging shall be processed to document functions leading to equipment alarms and trips, performs input and operation function checks and provides historic event recording of the station events. Input signal shall be filtered for noise rejection and shall have programmable time delay function for each input.

The reporting software shall allow customization of sample reports and designing of report format for any of the stored data.

TE-5.4 PROTECTIVE RELAYING SYSTEM

TE-5.4.1 Protection

The protective functions and settings shall be in software uploaded into the relays from a laptop computer. The relays shall provide protection for the generator, transformer, bus and line as shown on Single Line Diagram Drawing.

The relays shall accept outputs from external equipment and devices such as transformer hot spot temperature, gas accumulation, vibration alarm etc., to provide additional protection.

The relays shall include programmable logic to allow implementation incorporating external/internal inputs to permit tripping schemes such as breaker failure functions and those as required for protection of the units.

Output contacts of the relays shall be connected to lockout or shutdown relays to permit tripping of the generator breaker, shutdown of the governor, excitation system etc. The proposed trip matrix and interfacing to other equipment shall be submitted with Bids.

TE-5.4.2 Protective Shutdown

Protective shutdown functions shall be provided to safely shutdown the unit in the quickest possible manner to minimize effects from abnormal electrical and mechanical operating conditions. Protective relays and other devices shall trigger lockout relays (86) Other functions shall include initiation of the breaker failure functions and transfer trips to remote line breakers. Below is a description of the various shutdowns.

TE-5.4.2.1 Lockout Shutdowns

For Hydro Generator with Excitation

- a. Unit lockout electrical shutdown (86E)

This shutdown shall be initiated by the unit protective relays. The 86E shall trip the generator breaker, close guide vanes, close inlet valve and remove the field immediately. The relay shall also initiate a unit shutdown sequence 5B and breaker failure protection. The unit is expected to go into overspeed momentarily.

- b. Unit lockout mechanical shutdown (86M)

The shutdown shall be triggered by mechanical or thermal devices for conditions which are of no immediate concern and the unit may be shutdown normally. The relay shall close a contact to the governor for normal shutdown. The UCS shall also execute a normal shutdown sequence 5B.

For Hydro Generator with Converter

a. Unit lockout electrical shutdown (86E)

This shutdown shall be initiated by the unit protective relays. The 86E shall trip the converter, close guide vanes and close inlet valve.

TE5.4.3 Hydro Generator Protection

- overspeed relay (12)
- synchronous speed relay (13)
- underspeed relay (14)
- undervoltage relay (27G)
- generator reverse power relay (32G)
- bearing protective device (38)
- mechanical condition monitor (vibration) (39)
- loss of excitation relay (40G)
- negative phase sequence relay (46G)
- thermal relay (49G)
- instantaneous overcurrent relay (50)
- breaker failure relay (50BF)
- generator overcurrent relay (51G)
- generator overvoltage relay (59G)
- voltage balance relay (60G)
- over/under frequency relay (81)
- generator differential relay (87G)

In case of a generator with converter, these shall be also implemented;

- Underpower relay (37)
- Running Circuit Breaker (42)

TE-5.4.4 Generator Transformer Protection

- synchronism-check device (25)
- instantaneous low voltage protective relay (27R)
- under over voltage protection (27/59)
- directional power relay (32)
- transformer thermal relay (49T)
- neutral differential protective relay (50/51N)
- transformer differential protective relay (50/51T)
- line overvoltage relay (59L)
- transformer ground protective relay(64T)
- directional power relay (67)
- neutral directional overcurrent (67N)
- phase angle measuring relay (78)
- frequency relay (81)

- rate of change of frequency (81R)
- transformer differential protective relay (87T)
- gen-transformer differential relay (87GT)

TE-5.5 REQUIRED PARTS

The Contractor shall recommend the type and quantities of spares for the UCS and associated equipment. The following required minimum spares shall be supplied:

- One (1) of each type CPU module for DCS/PLC
- One (1) of each type power supply module for DCS/PLC
- Two (2) of each type communication cards for DCS/PLC
- One (1) of each type of I/O cards for DCS/PLC
- One (1) of protective relaying system completed with CPU, power supply, communication cards and I/O cards

One complete set of spare parts described above is defined as the total number of the parts required for one unit of the equipment specified in this Chapter.

Each type of spare parts stands for the different parts in sizes, pressure or current ratings, functions, etc.

TE-5.6 OPERATION AND MAINTENANCE MANUALS

The Contractor shall provide operation and maintenance (O&M) manuals for the control, monitoring and protection system and associated equipment. The O & M manuals shall include the following:

- Description of the control system, monitoring system, protection system, associated equipment, IEDs and designed functions.
- Description and data sheets for the relays.
- Description and data sheets of other associated equipment and components
- Description and documentation of the control, application, and operator control station software
- Test and commissioning results and data, alarms, trends, and alarm summary reports.
- A set of as-built block, schematics, and wiring diagrams.

TE-5.7 POWER QUALITY METER (PQM)

The Contractor shall provide Power Quality Meter equipment and accessory conform to PEA Interconnection Code 2016 or latest version, and must be responsible for the expense including communication service fees for the first year.

TE-5.8 ELECTRICAL AND CONTROL EQUIPMENT BUILDING

Electrical and Control Equipment Building shall consist of switchgear and control equipment room. The building shall be designed for convenience in operation and the equipment shall be spaced to permit easy circulation, easy access to equipment for repair or replace unit, and convenient installation of future equipment. The building structure shall be reinforced concrete with metal roofing or container building.

TE-5.8.1 Container Building (If applicable)

The container building shall be designed for convenience in operation. The modular containers shall be spaced to permit easy circulation, easy access to equipment for repair or replace units, and convenient installation of future equipment. Block out or open channel shall be provided for cable of electrical & control equipment and hydraulic system.

TE-5.8.2 Outdoor Electrical Equipment Area (If applicable)

The outdoor electrical equipment area shall enclose switchgear, communication cubicle, auxiliary power supply, electrical equipment etc. All foundations shall be constructed with reinforced concrete supported on shallow or piles.

The top surface of equipment foundations shall be elevated at least 1.0 m. above the surrounding site finished grade. The top surface shall be finished with the slope of 1:100 in outward directions to avoid any water pound on the surface. Stairway and walkway around the equipment shall be provided for maintenance access purpose.

The ground surface within the outdoor electrical equipment area shall be graded for drainage and surfaced with at least 0.15 m. thick of crush stone no.2.

End of Chapter

TE-7 MEDIUM VOLTAGE SWITCHGEARS

EQUIPMENT WORKS**ELECTRICAL EQUIPMENT – TECHNICAL SPECIFICATIONS****TE-7 MEDIUM VOLTAGE SWITCHGEARS****TABLE OF CONTENTS**

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TE-7 MEDIUM VOLTAGE SWITCHGEARS

TE-7.1 RATING AND CHARACTERISTICS

TE-7.1.1 General

The MV switchgears shall include the necessary equipment of the MV panels, circuit breakers, fuses, disconnecting switches, voltage and current transformers, busbars as well as all auxiliary electrical or mechanical equipment or materials required for the completion and the operation of the system described.

Furthermore the switchgears shall be completely wired with all its equipment properly mounted and interconnected. Layout arrangement of all equipment installed in switchgear room e.g. MV switchgear, station service transformer enclosure, LV switchgear etc. shall be proposed by Bidder with his Bid.

The switchgears panel shall conform in all respects to the IEC Standard 62271-200 "High-Voltage metal-enclosed switchgear and control gear" except if otherwise specifically stated elsewhere in this specification.

In case of the designed operating voltage is below 1 kV, the contractor shall designed to conform technical requirement referring to the TE-8 Low Voltage Switchboards.

Furthermore, the terms used under this specification are to be understood with the meaning determined by the above Standard specification.

TE-7.1.2 Rating and Characteristics

The MV switchgears shall have the following main rating and characteristics

(a)	Operating Voltage	kV	22	3.3
(b)	Rated Voltage	kV	24	3.6
(c)	Rated 1 min power frequency withstand voltage			
	- To earth between poles and across open switching device	kV	50	10
	- Across the isolating distance	kV	60	12
(d)	Rated lightning impulse withstand voltage (1,2/50 μ s)			
	- To earth between poles and across open switching device	kV _{peak}	125	40
	- Across the isolating distance	kV _{peak}	145	46
(e)	Rated short-time withstand current, 1 second short circuit duration	kA	25	16
(f)	Rated peak withstand current	kA	63	63
(g)	Rated frequencies	Hz	50	50
(h)	Degree of protection of enclosure		IP41	IP41

The equipment mounted inside the panels shall conform to the requirements of item 7.4 of this Section.

TE-7.2 MV SWITCHGEAR PANELS GENERAL DESCRIPTION

The equipment required for the following panels shall be according to the single line diagram.

- 3.3 kV VT, CT panel boards (incoming feeder from generator) (for 3.3kV generator)
- 3.3 kV generator circuit breaker panel board. (for 3.3kV generator)
- Load break switch panel board. (if applicable)
- 22 kV circuit breaker panel board.
- 22 kV VT, CT panel board.

Suitable panel form and compartment separation in accordance with Standard Specification IEC Standard No.62271-200, shall be provided for satisfactory connection of the switchgear to the MV cable. Personal safety shall be improved by deflector plates of adequate height, installed by the Contractor, attached to the top of the panels.

TE-7.3 MV SWITCHGEAR PANELS DETAILED REQUIREMENTS

TE-7.3.1 General

a. Construction

The metal enclosures permanent or removable partitions and the inspection windows of the panels shall be capable of withstanding permanent or elastic distortion so that the protection degree which they afford should not be reduced. The control levers of the devices, the interlock latches and mechanical drive systems shall be capable of resisting to a force of at least 500N without any distortion or breaking, such force to be applied in the most adverse manner to the accessible part of such mechanisms. In addition, the driving mechanisms shall have their weakest point in such a position that, in case of breaking or distortion, no danger shall arise for the operator and their repair shall be as easy as possible.

The reinforced with ribs sheet-steel doors shall be provided with at least three (3) points central lock suitable to withstand the arcing pressure relief and the thermal effects of arc. Resistance to internal arcing shall be in compliance with IEC 62271-200 (submit certified test report of previously performed tests). Inside all panel boards suitable heaters shall be installed, controlled by thermostat to protect condensation.

Provisions shall be made for drawing out the MV circuit breaker manually into test and complete isolating positions with safety. Suitable interlocking shall be provided for drawing-out procedure.

b. Insulation

The solid insulating materials to be used shall be self-extinguishing and shall have an insulation level equal to the rated insulation level of the panel.

c. Metal Enclosure

The panels shall be fitted with a metal enclosure covering all their elements, (including the bottom) and providing a protection degree IP4X, as specified in IEC 62271-200, against accidental contact of persons with live parts. All the panels of a group shall be separated each other by using a metallic partition, which shall be extended throughout the depth of the panel and upward at least up to the partition of the bus-bar.

Low voltage compartments shall be provided to install all protective relays (if applicable) monitoring and control device.

The panels of MV switchgear shall be operated locally at the front of GCB panels and LCB panels.

The panels shall install on the base frame.

Ground bus shall be provided in cubicle.

Each switchgear shall be furnished with lighting system, space heater and thermostatic control to prevent condensation of moisture.

d. Visual Verification

A possibility shall be provided for visual verification (through a inspection window made of safety class, meeting the requirements of IEC 62271-200) of proper performance of manipulations in particular those of the isolating devices. In case of such visual verification of the isolation is not possible this shall be made by reliable other means, at the discretion of the Engineer.

e. Ventilating Openings and Vent Outlets

These openings and outlets shall be in conformity with the requirements of IEC 62271-200. Ventilation openings shall be provided at appropriate locations so that on the one hand staff standing in front of the panels, whether doing switching operations or not, may not run any risk and on the other hand, mounting the panels against a wall shall be possible.

f. Partitions and Shutters

The partitions and the shutters shall be in conformity with the requirements of IEC 62271-200. In addition to the above requirements, if any partition or shutter is made of insulating material (this being permitted only in case where it cannot become part of the metal enclosure) this material shall be self-extinguishing, shall not emit corrosive gases and shall be accompanied be references (given by the manufacturer) for successful use.

g. Anti Corrosive Protection and Painting

All non-live metal parts which are galvanized and electro-galvanized shall be painted to provide protection against corrosion. The epoxy paint shall have a thickness of at least 50 microns. The color shall be defined by Engineer later. The bolts, nuts and other fittings to be used shall be of stainless steel or they shall be protected by suitable metal coating.

h. The following works shall be performed by a person facing the front side of the panel without any danger :

- Making and breaking of the main circuit.
- Verification of isolation either visually or by other equally reliable means.
- Earthing and short circuiting operation.
- Padlocking.

TE-7.3.2 Earthing Operation

All components of the compartment of a panel, in which work is being carried out and which are electrically connected to circuit elements outside the above compartment, shall be earthed. The verification, of the above earthing shall be carried out visually as well. If the construction arrangement of the panel does not permit visual verification the position of the movable contacts of the device, such verification shall be made by other indisputably reliable means. The foregoing do not apply to main bus-bar i.e. the bus-bar which are common in adjacent panels.

TE-7.3.3 Protection of Persons against Accidental Contact -Access to the Interior (not applicable)

TE-7.3.4 Bus-bar, Access (not applicable)

TE-7.3.5 Interlocks

The following interlockings shall be achieved by means of simple and direct mechanical arrangements (the use of keys to that effect being prohibited). As the connection of the interrupting device to the bus-bars shall be achieved through an isolator, the interlocks required (IEC 62271-200) shall be such as:

- Not to permit operation of the isolating device unless the main interrupting device is in the open position.
- Not to permit operation of the main interrupting device unless the isolating device is fully closed or open.
- Not to permit the operation of the earthing and short-circuiting device unless the main circuit has been isolated from the bus-bars.
- Not to permit the isolator to close before the earthing is removed.

TE-7.3.6 Access to the Voltage Transformers Panel

Access to the voltage transformers panel shall be possible only after:

- The transformers have been compulsorily isolated from MV such isolation to be ensured by means of suitable mechanical interlocks.
- The alive elements have been fully covered by a permanent or inserted partition.

After the opening of the door providing access to the interior of the panel, the closing of the isolators and the removal of the bus-bars covering should be precluded (by means of interlocks).

As an alternative the voltage transformers may be mounted on a truck, in which case their isolation, from the MV side as well as from the LV side shall be achieved by removing the transformers themselves, the respective isolators being omitted. The voltage transformers shall be accessible when the truck has exceeded the isolation position and the alive fixed contacts have been automatically covered. The voltage transformers shall be protected by high breaking capacity fuses.

TE-7.3.7 Earthing

A main earthing copper bus of minimum cross-section of 50 mm², running along the entire length of the switchgear shall be provided for earthing, in accordance with IEC 62271-200.

External panel enclosure, metal partition, hinged doors, movable contacts of earthing devices, metal parts accessible from outside and every item of the switchgear which has to be earthed, shall be connected to this bus with flexible or solid connections as required.

Finally, the secondary windings of all current and voltage transformers as well as metallic sheath of all plastic cables shall be connected to the main earthing bus by means of copper conductors the length of which shall be as short as possible. The latter shall be equipped at both ends with appropriate connectors for its connection to the main grounding grid by means of 95 mm² conductor.

TE-7.3.8 Provision for Padlocking

Padlocking shall be provided for the main interrupting device isolator and earthing and short-circuit device.

TE-7.4 MV SWITCHGEAR EQUIPMENT SPECIFICATIONS

TE-7.4.1 Scope

This paragraph covers the overall requirements to which the equipment mounted on the MV switchgear shall comply.

TE-7.4.2 MV Circuit Breakers

- a. Applicable Standards

- The circuit breakers shall conform in all respects to the IEC Standard 62271-100 "High voltage alternating current circuit breakers".

b. Main Characteristics

Three (3) poles, Vacuum indoor, draw-out type, shall have all the electrical characteristics mentioned in the item 7.1.2 herein as well as the following :

- Rated voltage kV	kV	24	3.6
- Rated current:	A	To be defined by the Contractor	
- Rated minimum short -circuit current :	kA	25	16
- Rated short-circuit making current	kA	63	40
- Rated operating sequence:		O-3min-CO-3min-CO	
- Rated supply voltage of closing and opening devices:		48 V DC	
- Rated supply voltage of auxiliary circuits:		230V AC 50 Hz or 48 V DC	
- Max interrupting time	cycle	5	5

Vacuum circuit breaker shall have surge absorber.

c. Operating Mechanism

The circuit breakers shall be closed by energy storage in springs (Stored energy operation). The charging of springs shall be done by a 48 V DC motor (motor charging). Charging of the springs or weights shall be possible to be done manually. The end of energy storage shall not initiate the closing operation of the circuit breaker.

Furthermore, the circuit breakers shall not allow a closing operation if there is an opening order the moment the closing order is initiated (circuit -breaker with lock-out preventing closing). The order for closing and opening operations of the circuit breaker shall be initiated either manually or by means of auxiliary control circuit. The auxiliary control circuits shall initiate the opening operation by an interruption of their circuit so as to ensure that the circuit breakers shall open upon loss of voltage in the auxiliary control circuits. The auxiliary devices shall be connected to the circuit breaker with a plug.

Since the operation of the circuit breakers shall be remotely controlled from the control panels beside the local or remote change-over switch a further possibility to limit the local manual operation shall be foreseen, as well as four indicating lights and push buttons.

The circuit breakers shall be equipped with then (10) auxiliary contacts for the control and annunciation circuits. The type of contacts will be as follows: 5 "normally closed", 4 "normally open" and 1 change over. They shall also be equipped with a position indicator showing whether open or closed. These indicators shall be mounted at convenient locations to be clearly visible from the front through appropriate inspection windows.

The circuit breaker shall have equipment for protecting abnormal functions as following:

- Anti-pumping
- Under voltage
- Two (2) trip coils

The position of circuit breakers shall be designed to support test position and draw-out position.

The operating mechanism shall be Trip-free. The spring shall be automatically recharged by the electric motor, and manually if the power supply should fail. Solenoid-type operating mechanism will not be accepted.

- Service position :
 - Circuit breaker completely inserted.
 - Power circuit and control circuit connected.
- Isolated (test) position:
 - Circuit breaker isolated.
 - Power circuit disconnected, control circuits connected.
- Removed position:
 - Circuit breaker draw-out completely.
 - Power circuits and control circuits disconnected.

TE-7.4.3 Load Break Switches for Station Service Transformer (If applicable)

a. Applicable Standards

The load break switches shall conform in all respect to the IEC standard 62271. The load break switch shall be installed if it is shown in the single line diagram.

b. Main characteristics

The three -phase load break switches shall have all the electrical characteristics mentioned in the item 7.1.2 herein as well as the following:

- | | |
|---|--|
| - Rated current | To be defined by the Contractor |
| - Rated mainly active load breaking current : | Equal to the rated current of the switch |
| - Rated closed loop breaking current: | To be defined by the Contractor |
| - Rated transformer no -load breaking current (minimum) : | To be defined by the Contractor |
| - Rated short circuit making capacity: | To be defined by the Contractor |

c. Operating Mechanism at Load break Switch

The load break switch shall be closed manually. The load break switch shall be equipped with an appropriate mechanism to open automatically when one of the fuses collaborating with it has blown. This release will actuate mechanically the same mechanism as that actuated by a blowing fuse. Finally the switches shall be equipped with number of auxiliary contacts necessary for the annunciation of their position (open or closed) as well as the annunciation of their opening.

TE-7.4.4 MV Disconnecting Switches

The disconnect switches shall be three-pole, single throw, outdoor, vertical break air switch type having all electrical characteristic mentioned in the item 7.1.2 herein. Rated current is 600A. The outdoor switch shall be installed on concrete pole connected to each 22kV network line (PEA), complete with steel base, insulators, silver coated contacts, terminals, blades, steel operating rod and pad lock and shall be manually operated on the ground level.

TE-7.4.5 MV fuses

a. Applicable Standards

The HV fuses shall conform in all respects with the IEC 60282-1 "Current-limiting fuses".

b. Main Characteristics

1. Type: Current -limiting fuses suitable for indoor installation and intended for voltage transformer protection.

2. Rating of the fuse-base :

The fuse bases shall be of rated voltage 24 kV and 3.6 kV and shall be capable of accommodating apart from 24 kV and 3.6 kV fuse links respectively.

Rated current:

To be defined by the Contractor

Rated insulation level:

as per item 7.1.2. herein.

3. Ratings of the fuse -link :

Operating voltage:

24 kV or 3.6 kV

Rated current:

To be defined by the Contractor

Rated breaking capacity:

To be defined by the Contractor

Network short-circuit capacity:

25kA

Rated minimum breaking current: Shall not exceed 4.5 time the rated current. Precise value shall be determined by the Contractor.

4. Characteristics of the fuse-link:

- Time -current characteristics:

Shall be given by the Contractor in accordance with the requirements of the IEC 60282-1.

- Cut-off characteristics shall be given by the Contractor.

- Fuse failure status shall be sent signal to UCC.

TE-7.4.6 Instrument Transformers

Current and voltage transformers shall be provided in isolate compartment from generator circuit breaker compartment as shown on the drawings and specified hereunder. Those CT and VT connected between generator and generator circuit breaker (GCB) board shall be provided separated board from GCB board. Instrument transformers shall have an accuracy class adequate for proper protective relaying and metering requirements and shall be in accordance with IEC 61869-3 for current transformers and IEC 61869-3 for voltage transformers. Voltage transformers shall be stationary mounted cast resin insulated. Current transformers shall be as required, either ring type with insulated conductor passing through center opening, or insulated wound type with primary and secondary windings.

The instrument transformers shall be provided with test plug.

The meter shall have its current and voltage transformers, separately from the others instrument, having the following requirements:

- CT accuracy class 0.5, burden not less than 15 VA.
- VT accuracy class 0.5, burden not less than 25 VA.

The secondary winding of 1 A shall be used for CT as well as $110/\sqrt{3}$ V shall be used for VT.

The current transformers shall have rated continuous thermal current 1.2 times rated primary current referred above. The current error and phase displacement shall be retained up to this value of thermal current. The thermal rating of the CT shall be same as the switchgear rating. The accuracy class for windings intended for protection shall be 5P20. The accuracy class for windings intended for measurement shall be 0.5.

The rated insulation level of voltage transformer shall be in accordance with IEC 61869-3 rated voltage 24 kV and 3.6 kV. The rated voltage of the VT shall be 1.2 for continuous operation and its accuracy class 0.5 and 3P.

The rated output of the current and voltage transformers shall be calculated by the Contractor according to the burden connected to their secondary terminals. The Contractor shall submit certified test reports for the current and voltage transformers before their shipment.

Instrument transformers for Revenue meter

Current transformers (CTs), each CT shall have two (2) cores for main and backup energy meter of each circuit of transmission line, the accuracy class of all cores are 0.2s complying with IEC 61869 standard or equivalent IEC standard latest version. Rated secondary current of each CT shall be suitable for the measurement associated with the above energy meters.

Inductive voltage transformers (VT), each VT shall have two (2) cores for main and backup energy meter of each circuit of transmission line, the accuracy class of all cores are 0.2 complying with IEC 61869 standard or equivalent IEC standard latest version. Rated secondary voltage level of each VT shall be suitable for the measurement associated with the energy meters.

TE-7.4.7 Voltage Indication for the Cable Ends (not applicable)**TE-7.4.8 MV Lightning Arresters****a. Applicable Standards**

The lightning arresters shall be non-linear resistor type conformed to IEC Standard 60099-1 or approved equal. The rating of the arresters shall be determined by the Contractor, in order to avoid insulation failures of the different type equipment connected to the system. The arresters shall be in accordance with IEC Standard 60099-1 and shall have the following characteristics:

b. Main characteristics

- System rated voltage (phase to phase) 22 kV and 3.3 kV
- Maximum continuous system voltage (phase to phase) 24 kV and 3.6 kV
- Rated frequency 50 Hz
- Rated discharge current
- Heavy duty arresters as required

c. Requirements for lightning arresters

The lightning arresters shall be of special station class, valve type, single pole with adequate rating, as approved by the Engineer. They shall be connected to each phase bus and shall be suitable for surge protection.

TE-7.5 SPECIAL TOOLS AND DEVICES

One (1) set of accessories shall be furnished, which shall include necessary devices for withdrawing and inserting the circuit breakers and also any special tools required for normal maintenance work.

TE-7.6 FACTORY ASSEMBLY, INSPECTION AND TESTS**TE-7.6.1 Routine Tests**

The switchgears shall be completely assembled, wired, adjusted and tested at the factory. After assembly, the complete switchgear shall be tested for operation under simulated service conditions to assure the accuracy of the wiring and the functioning of the equipment, including interlocks as specified herein. The main circuits shall be given a dielectric test of the required volts in accordance with applicable IEC Standards, 50Hz, for one (1) minute between live parts and ground and between opposite polarities. The wiring and control circuits shall be given a dielectric test of 1500 volts 50Hz, for one (1) minute between live parts and ground. Measurements of the resistance of the main circuit, mechanical operation tests and partial discharge test to component or devices with compact solid installation (insulators for bus-bars supporting, voltage dividers etc). Tests shall be in accordance with applicable IEC Standards

TE-7.6.2 Type Tests

Design of the MV switchgear shall meet all the requirements of these Technical Specifications. The following type tests shall be performed by the Contractor at his own expense in accordance with applicable IEC Standards, unless the Contractor can submit certified test reports of previously performed design tests on panels of identical rating and design constructed by the same manufacturer for approval by the Engineer:

1. Lightning and switching impulse Voltage tests.
2. Power frequency voltage tests on the main circuit.
3. Partial discharge tests.
4. Dielectric tests in auxiliary and control circuits.
5. Temperature-rise test.
6. Short-time and Peak withstand current tests.
7. Measurement of the resistance of the main circuit.
8. Verification of making and breaking capacities.
9. Mechanical operation and robustness test.
10. Verification of the degree of protection.
11. Measurement of leakage currents.
12. Test of mechanical robustness of the enclosure.
13. Tests of accuracy (for instrument transformer). The Engineer, however, reserves the right to request the repetition of any type test in the presence of his representatives, but in case that it proves successful, all relevant expenses shall be charged to the EGAT.

Components contained in metal enclosed switchgear which are subject to individual specifications (IEC) shall comply with and tested in accordance with these specifications. The Contractor shall submit to the Engineer test certificate issued by Recognized Laboratory for approval.

TE-7.7 REQUIRED PARTS

The Contractor shall furnish the following :

TE-7.7.1 Circuit-Breakers (NOT APPLICABLE)

TE-7.7.2 Load Break Switch (NOT APPLICABLE)

TE-7.7.3 Disconnecting Switch (NOT APPLICABLE)

TE-7.7.4 Fuse

- One (1) fuse-base (for 3 phase)
- Six (6) fuse-links

One complete set described above is defined as the total number of the parts required for one unit of the equipment specified in this Chapter. Each type stand for the different parts in sizes, pressure or current ratings, functions, etc.

TE-7.8 PREREQUISITES FOR ACCEPTING THE PANELS (not applicable)

End of Chapter

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TE-8 LOW VOLTAGE SWITCHBOARDS

EQUIPMENT WORKS**ELECTRICAL EQUIPMENT – TECHNICAL SPECIFICATIONS****TE-8 LOW VOLTAGE SWITCHBOARDS****TABLE OF CONTENTS**

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TE-8 LOW VOLTAGE SWITCHBOARDS

TE-8.1 DETAILED REQUIREMENTS

TE-8.1.1 General

The LV switchboards shall be provided as follows:

- a. AC switchboards
- b. 48 V DC distribution panel
- c. 230 V UPS distribution panel
- d. Local control panels or Junction Box

TE-8.1.2 AC Switchboards

- a. General

All switchboard shall be a standard indoor switchboard as described herein and shall be of suitable self-supporting cubicles containing an assembly of circuit breaker feeders and motor starter feeders with all necessary instruments such as CT, meter, relay etc.

Power supply system shall be TN-S to all required cubicles/loads, at least, as follows:

- a. 48 V DC battery charger panel and Distribution board
- b. Distribution panel boards

The panel boards shall be completely built, wired, painted and tested in the factory. The panel boards shall be designed, manufactured and tested in accordance with the requirements of the latest recommendations of the International Electromechanical Commission (IEC) Publication 61439 for “Factory-built assemblies of LV switchboard and control gear”, 60529 for “Degree of protection”, 60947-2 for “Circuit- Breakers”, and 60947-4 for “Contactors and motor starters”.

The switchboard design shall be verified through a comprehensive process that includes type test or calculation/measurement and the application of constructive rules to ensure compliance with the requirement of IEC 61439.

The panel boards shall be of interchangeable design, bolt-in type breaker, free standing and front-connected including main incoming line connections. Any other design shall be approved by EGAT.

The design on the basis of which the switchboard panels are to be constructed, must have already operated satisfactorily by providing references and certified test report for

approval. The Contractor shall install inside all panel board suitable heaters, controlled by adjustable thermostats, LED lighting and universal socket.

The bottom shall be opened for stubbing in the conduits or cables entering from below. There shall be no cross bracing within one hundred and fifty (150) millimeters of the floor. Protection against direct contact with live part shall be provided. Height of each adjacent panel shall be uniformity.

An automatic transfer switch (ATS) shall be built into the LV switchboard for a future power source.

b. Bus Details

The main horizontal bus for the auxiliary panel board shall be rectangular hard drawn copper bus, as approved by EGAT and shall have a current carrying capacity of not less than that of the incoming breaker. Apart from the bus bars (three phase and neutral) the panel board is equipped with a ground bus at the bottom of the structure and accessible from the front.

Connections from the main horizontal bus to the individual starters and for feeder units within a vertical section shall be made by means of a common vertical bus or by separate cables to each unit. Connections shall have adequate current carrying capacity to supply the motors and feeders.

Bus supports shall be of high dielectric strength, low moisture absorption, moulded compound with high impact strength, and long creepage surface. All bus work, connections, and termination, shall have a maximum temperature rise of 50°C under full-load conditions.

c. Wiring Details

Wiring of panel board shall conform to IEC Standards. Internal panel wiring shall be of cross-sectional area 1.5 square millimeter minimum, stranded single conductor, 600 volt wire, thermoplastic -insulated. Leads for connection to devices which are located outside the panel board shall be extended from the terminal blocks in the individual compartment to master terminal blocks. Color of wiring inside shall conform to EGAT's requirement unless otherwise agreed.

All termination points shall be clearly marked with identifying numbers not duplicated elsewhere on the equipment as approved by the Engineer. Terminal blocks shall have insulating barriers between studs. The CT short link terminal block shall be provided.

The Contractor shall furnish elementary, connection and interconnection wiring diagrams for the Engineer's approval. Connection diagrams shall be secured on the inside of each compartment door and protected against humidity and temperature.

- d. Circuit breakers shall be of molded case type or miniature type. Circuit breakers shall be manually operated three-pole, 400 V AC, or 230 V AC, or suitable for DC operation, two-pole 48 V. All multi pole circuit breakers shall be so designed that an overload on one pole will automatically cause all poles to open. Interrupting capacity of the 400 V AC circuit breaker, shall be not less than 12 kA, for the molded case circuit breakers, while for the miniature circuit breakers 400V and 230V AC, shall be not less than 10 kA. All circuit breakers shall have thermally operated inverse time tripping elements in accordance with IEC Publication 60947-2. One (1) magnetic trip element per pole shall be provided for instantaneous tripping of short circuit currents. The operating mechanism of all circuit breakers shall be trip free and the stationary and moving contacts of all breakers shall be of non-welding silver alloy with arc quencher.

Miniature type circuit breakers shall be used for secondary branch circuit breaker, 40A trip rating and less. Its magnetic trip range, for ac operation, shall be either 3 up to 5 times the rated current or 7 up to 10 times approximately the rated current.

Generator circuit breakers (GCB) (if applicable) shall be Three (3) poles, air circuit breaker, indoor, draw-out type, motor operation suitable for 48 VDC and have all the electrical characteristics such as rated voltage, rated current, rated breaking capacity, rated making capacity and short-time withstand current at 1 second based on generator. Life cycle of mechanical without maintenance. Calculation documents shall be submitted to and approved by EGAT's Engineer. The GCB shall meet the requirements of latest respective IEC 60947 standard. The panel for GCB shall meet the requirements of latest respective IEC 61439 standard, forms of separation 2B. For distribution board busbar shall be separated.

All circuit breakers shall be provided with at least one set of auxiliary contacts for control and position monitoring (one NO and one NC shall be provided). The switchboards shall be provided with spare feeder of not less than ten (10%) percent of the essential circuit breakers.

- e. Motor starters

Starters shall be combination magnetic type with circuit protective device and magnetic starter. AC motor starters shall in general be designed for across-the line starting. AC motor with rating greater or equal to 7.5 kW shall be designed for star -delta starting.

Each starter shall be sized according to the kW rating of the motor and shall be completed with overload relay with thermal elements in accordance with the motor current and time relay for star-delta starting. Starters shall have not less than four (4) auxiliary switch contacts.

Each starter shall be equipped with a three-pole, 400V AC, circuit breaker of molded case type complete with adjustable thermal and magnetic trip elements.

Each starter shall preferably be equipped with a common manual reset button mounted on the front plate.

Control transformer with secondary fuses shall be supplied (if required). Control voltage for starters shall be 230V AC or 48 V DC properly protected. All starters shall conform to IEC Publication 60947. For single-phase fractional horsepower motors, where remote or automatic control is not required, manual starter switches equipped with suitable rated thermal element may be used.

f. Push buttons and Indicating lights

Where required, compartments shall have push-buttons and indicating lights flush mounted on the front plates. These push buttons shall be of the heavy duty, oil tight type, with contacts of continuous rating 10 amperes, 500 volts ac or dc. Stop push buttons shall not be a part of the reset push button.

g. Protection relays

The protective relaying for the main AC and DC switchboards will be in accordance with current practices which have been well-proven and effective, ensuring continuity of service and high reliability. Relays shall be provided with adjustable setting for the operating thresholds which will be calculated by the Contractor.

TE-8.1.3 DC Auxiliaries Switchboard

The power station shall be equipped with the following :

The switchboard shall consist of an assembly of structures as described herein.

The charging rectifier unit shall provide a floating charge to a 48 volts Valve Regulated Lead Acid (VRLA) type battery specified in TE-9 of these Technical Specifications.

TE-8.1.4 Requirements for Distribution Panel Boards

These panels shall be conventional, general purpose, indoor, self-supporting cubicle or surface mounted type, meeting the requirements of the applicable IEC Standards, suitable for 400 volt, 3 -phase, 50Hz, four-wire, or 230 volt two-wire supply as specified. The panel-boards shall be completely assembled, wired, painted and tested in the factory. The panel-boards shall be provided with spare spaces corresponding to twenty percent (20%) of the specified circuit breakers. Panel-boards shall be constructed from two (2) millimeter thick sheet steel with full height vertical trough, complete with cable tie supports, as well as ample wire trough at the top and bottom of each panel, for all wiring and connections, removable front door and trim interior back panel, required circuit breakers and all necessary hardware and accessories required for a complete installation.

The panel for Main Distribution Boards (MDB) shall meet the requirements of latest respective IEC 61439 standard, forms of separation 2B.

Precaution apertures shall make possible to control main circuit breaker through the front plates. The front plates shall also ensure protection against direct contact with live parts. Front

plates may be of small "door" type, each one easily dismantled with a simple locking system, with a part cut-out for the passage of the units control (i.e. miniature circuit breaker or switch etc).

Neutral bus shall be fitted with terminals complete with lugs or clamps of sufficient quantity to accommodate the number of branch circuits in the panel-board. Panel-boards shall have a ground bus for the connection of the ground wires. Ground bus and neutral bus shall be solid copper bars. Each panel-board shall have an identifying name plate of laminated phenolic with white letters on a black background. Nameplates shall identify the panel-boards by number and name. A suitable card holder with circuit identification card shall be mounted on the inside of the panel door. Inscription for nameplates and cards shall be in English approved by EGAT.

Circuit breakers shall be manually operated, three-pole, 400V AC or 230V ac and their characteristic shall be as described in item 8.1.2.d herein. Contactors shall be three-pole, 400 volt AC, designed to operate satisfactorily at the power plant on line voltages of 85 percent to 110 percent of rated voltage. Contactors shall comply with IEC Standards and shall be of continuous rating.

Contactors shall be capable of making and breaking the rated current and of carrying this current without damage continuously. They shall also be capable of withstanding without damage the passage of the maximum current until such time as the fault is cleared by the operation of the circuit breaker.

All contactors shall be fitted with arc shields and magnetic blowouts and all parts which may require renewal, adjustment or inspection, shall be readily accessible. Contactors shall be of the self-cleaning pattern and designed so as to prevent welding in. Each contactor in the panel board shall be so screened from adjacent units and current carrying parts, that it is possible to carry out, in safety work on its outgoing cable whilst other contactor equipment remains alive and on load.

The panel boards shall be equipped with all the necessary push-buttons, selector switches, transformers with relative fuses, indicating lights etc. required (as specified in para 8.1.2 herein) for control and monitoring of the motorized valves.

TE-8.1.5 Name Plates

Each circuit shall have a white plastic plate with black laminated name plate of minimum size twenty-five by seventy (25x70) millimeters with circuit designation cut through the surface black lamination. Each motor control center shall be equipped with a similar name plate approximately fifty by one hundred and fifty (50x150) millimeters in size. Inscriptions for all name plates shall be in the English, as approved by the Engineer.

TE-8.2 EQUIPMENT DETAILS FOR THE AC AND DC AUXILIARIES

The Contractor shall be responsible for design the quantity rating, sizing of all feeders circuit breakers, motor starter, AC/DC distributed circuits, CT, meter, transducer, relay etc., and

proposed with diagram during bidding. Final design shall be approved by the Engineer. At least the following feeder circuits shall be provided :

- Incoming feeder circuit, 3-phase, fed power from station service transformer.
- Outgoing feeder circuits for common auxiliary equipment, 3-phase e.g. battery charger, maintenance valve, inlet valve, crane (if applicable), lighting & small power, drainage pump. 1-phase e.g. inverter, MV CB control, heater.
- Motor starter feeder circuits for unit auxiliary e.g. oil pump, air compressor, water pump.

TE-8.3 FACTORY ASSEMBLY, INSPECTION AND TESTS

Routine factory tests shall be as required by the relevant IEC standards in accordance with the General Conditions. The panel boards shall be completely assembled, wired, adjusted and tested at the factory. Factory tests shall include functional and operational tests to check compliance with all requirements of this Section.

TE-8.4 INSULATION RESISTANCE TESTS

The insulation resistance to ground of windings of motors and all electrical equipment shall be measured and recorded after the installation but before any external wiring connections are made. The insulation resistance prior to energizing of any piece of equipment, shall not be less than the requirements of IEC standards and the Engineer's approval of the measured insulation resistance shall be obtained before these items of equipment are energized or operated under power. All insulated wires and cables shall also be tested for insulation resistance after installation.

TE-8.5 REQUIRED PARTS

The Contractor shall furnish the following :

- a. one (1) circuit breaker of each type
- b. one (1) magnetic contactor of each type
- c. two (2) fuses of each type
- d. one (1) relay of each type
- e. one (1) thyristor of each type
- f. one (1) meter of each type

One complete set described above is defined as the total number of the parts required for one unit of the equipment specified in this Chapter. Each type stands for the different parts in sizes, pressure or current ratings, functions, etc.

End of Chapter

TE-9 STORAGE BATTERIES AND BATTERY CHARGER

EQUIPMENT WORKS**ELECTRICAL EQUIPMENT – TECHNICAL SPECIFICATIONS****TE-9 STORAGE BATTERIES AND BATTERY CHARGER****TABLE OF CONTENTS**

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TE-9 STORAGE BATTERIES AND BATTERY CHARGER

TE-9.1 RATING AND CHARACTERISTICS

One (1) lot 2V Valve Regulated Lead Acid (VRLA) type storage battery shall be provided for the powerhouse 48 volts dc supply, providing a nominal voltage of 48 volts -15%,+10%. The battery shall have an ampere-hour capacity sufficient to maintain a load equal to the estimated sustained load of the equipment and emergency loads described herein and in the other sections of these technical specifications for a period of two (2) hours and after interruption of supply from the battery charger. The voltage at the end of the discharge shall be 1.75V/cell, at an average ambient temperature of 25 °C.

TE-9.2 BATTERY

TE-9.2.1 Design

The battery shall be sized in accordance with internationally recognized standard.

Standards	Title
IEEE-1187-2002	Recommended Practice for Installation Design and Installation of Valve-Regulated Lead Acid Batteries for Stationary Applications.
IEEE-1188-2005	Recommended Practice for Maintenance, Testing and Replacement of Valve-Regulated Lead Acid Batteries for Stationary Applications.
IEEE-1189-2007	Guide Selection of Valve-Regulated Lead Acid Batteries for Stationary Applications.
IEEE-1657-2009	Recommended Practice for Personnel Qualifications for Installation and Maintenance of Stationary Batteries.
IEEE 485-2020	Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications

The Contractor shall calculate the cell capacity required taking into account the temperature correction factor, design margin and the compensation for age, according to the recommendations of IEEE. If required, calculation sheets shall be submitted for approval.

TE-9.2.2 Requirement

The battery cell connectors, terminal, bolts and nuts shall be acid-resistance and made by manufacturer standard.

The battery shall be manufactured in the same lot and not exceed six (6) months before actual installation period or approval.

The battery shall be designed for a 10-year service life under float service conditions. Ventilation methods and ambient temperature calculations must be taken into consideration to ensure optimal performance and longevity.

TE-9.2.3 Battery installation

Battery cells shall be installed in an enclosed cubicle painted with acid-resistant paint and located in an electrical room or battery room. The cubicle must be designed to prevent corrosion and protect against electrolyte gel leakage in case of battery cell damage. It should comply with IP4X standards and include proper ventilation.

All air moved by the ventilation system should be exhausted to the outside atmosphere and must not re-circulate into other confined areas. This ensures that any potentially harmful fumes are safely removed from the building.

Alternatively, the contractor may design a wall rack mounting system. The installation location must be approved by EGAT to ensure it meets all necessary safety and operational standards.

TE-9.2.4 Accessories (If applicable)

TE-9.3 CHARGER

TE-9.3.1 Design

Battery charger characteristic shall be in accordance with IEC 60146

TE-9.3.2 Requirement

The charger rectifier shall be thyristor type voltage regulated with current limiting and transient surge protection preferably for 400 volt, 3-wire, 50 Hz supply. The continuous output rating of the battery charger shall be not less than normal load plus equalizing charging current.

Charger shall be capable of maintaining the battery at 2.18 volts per cell with plus or minus 1 percent accuracy. In addition, the charger shall be capable of automatically restoring the battery to the fully charged capacity, within ten (10) hours from a voltage of 1.75 volts per cell, and shall also be capable of supplying all continuous panel board loads in the bus section. The equalizing voltage shall be 2.35 volts per cell average according to IEC Standard 60146 or that voltage required by the battery. Alarms shall be provided for battery charger failure and low volt limits.

Silicon droppers shall be furnished on the DC bus for maintaining the DC bus at 48 V. They shall be automatically switchable between floating and equalizing charge mode. A manual Control shall also be provided.

Battery charger parameter setting shall be done at charger, essential local indicators and alarm shall be provided on front panel. Communication link to the powerplant control for alarm status, parameter monitoring and any equipment failure shall be provided.

No.	Description	
1	Capacity	Design by contractor
2	Input voltage	400 3p Vac \pm 10%
3	Frequency	50 \pm 5% Hz
4	Output voltage	48 Vdc
5	Ripple	\leq 2 % without battery

6	Operating temperature	0 – 40 (without derating), 95% Relative humidity
7	Protection degree	IP41
8	Cooling	Fan controlled and monitored
9	Communication	Modbus RS-485 or TCP/IP
10	Cable entry	Bottom

The 48 volt DC auxiliaries switchboard shall be 2 wire system and shall comprise one charger and the two pole line, for all DC loads as herein as well as required by the detailed design made by the Contractor and approved by EGAT.

TE-9.3.3 Charger panel

Charger panel for the powerhouse shall include, the charger and at least the following main circuit components :

1. AC contactor complete with overload elements and control switch for incoming supply. Fuse of adequate rating for rectifier output.
2. DC 2-pole circuit breaker, as well as load disconnecting switch for 48 V switchboard, of adequate rating for batteries output and rectifier output.
3. DC voltmeter, rectifier output and ac supply failure alarm relays, and zero to twenty four (0-24) hours equalizing timer.
4. DC shunts in rectifier output and battery incoming lines for indicating ammeters (one with zero center) mounted in the control board and rectifier bar.
5. Bus ground detection system, including alarm relay and indicating lights mounted on main control board.
6. Surge suppression devices.
7. Set of line terminating lugs for battery and load wiring.
8. Fault and status indicating lights for: charger on, mains failure, high DC Voltage, charger failure, battery disconnected, boost charging.

Expect DC load

- Turbine control & monitoring (incl. governor, inlet valve)
- Generator control & monitoring (incl. AVR, bearing)
- MV CB control & protection
- Unit protection
- Transformers protection
- Inverter
- Auto synchronizer

TE-9.4 TESTS

The Contractor shall perform standard routine tests during manufacture in the factory. Certified copies of design tests, including discharge test for capacity, shall be furnished to the Engineer for approval.

TE-9.5 REQUIRED PARTS

- a. One (1) thyristor or electronic control module board of each type
- b. One (1) molded case circuit breaker of each type
- c. One (1) fuse of each type (If applicable)

End of Chapter

TE-9A UPS SYSTEM

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TE-9A UPS SYSTEM

The UPS System shall include the Uninterruptible Power Supply equipment consisting basically of inverter, static by-pass switch and distribution board.

The UPS is required to supply power to all essential AC consumers which shall not tolerate any power supply interruption such as programmable logic controller (PLC), telecommunication equipment, revenue meter, fire alarm, fire exit lamp, etc.

Continuous rated output shall be determined by the Contractor taking into account margin for future load and compensation for age.

TE-9A.1 RATING AND REQUIREMENTS

The required main data shall be as follows:

Rated input voltage	VDC	48 - 15%,+10%.
Rated output voltage	VAC	230
Wave form		Sinusoidal
Wave distortion	%	5% THD
Rated output (p.f. 0.8 to 1 lag.)		To be determined by the Contractor and approved by EGAT
Rated output frequency	Hz	50
Output voltage variation	%	± 2 Steady state
Output frequency variation	%	± 0.5
Overload capability (inverter)		
- for 10 min	%	120
Efficiency	%	>80

TE-9A.2 DETAILED REQUIREMENTS

- The static inverter shall be designed for continuous operation and shall receive power supply from the 48 V DC distribution board.

The static by-pass switch shall automatically by-pass the inverter in case the inverter fails or in case of overload. The load normally supplied by the inverter shall thus be connected to the normal AC supply system without power interruption. Maximum total operating time of static transfers switch shall not be exceed 0.25 cycle in both directions. After recovery of normal power input condition, the load shall be connected to inverter by manual.

To fulfill this requirement it is necessary that the inverter output voltage and the normal AC voltage are synchronous.

A manual initiation of the static transfer switch shall permit functional tests.

Furthermore the manual by-pass switch shall allow to de-energize the inverter and the static by-pass switch (e.g. during repair or maintenance) without power supply interruption to the load.

The distribution board shall comprise molded case circuit breakers (MCCBs) for the outgoing feeders.

The inverter cubicle shall be of free standing, steel enclosure, IP 41, with front access for maintenance. Cable entry shall be provided at the bottom for cabling. Provision shall be made for sufficient ventilation to prevent overheating of equipment. Fans, if required, shall be provided as normal and standby units.

Necessary control equipment and monitoring instrument shall be provided on the front panel. Alarm and status indicator, protection functions and diagnosis functions shall be included.

TE-9A.3 FACTORY ASSEMBLY, INSPECTION AND TEST

Routine factory tests shall be as required by the relevant IEC standard in accordance with the General Conditions. The panel boards shall be completely assembled, wired, adjusted and tested at the factory. Factory tests shall include functional and operational tests to check compliance with all requirements of this Section. The UPS shall be subject to the following tests at the Contractor's shop in compliance with relevant IEC Standards.

TE-9A.4 REQUIRED PARTS

- a. One (1) electronic control module board of each type
- b. One (1) molded case circuit breaker of each type
- c. One (1) fuse of each type (If applicable)

One complete set described above is defined as the total number of the parts required for one unit of the equipment specified in this Chapter. Each type stands for the different parts in sizes, pressure or current ratings, functions, etc.

End of Chapter

**TE-10 CABLE TRAY, SUPPORTS AND CONDUIT
SYSTEM**

EQUIPMENT WORKS**ELECTRICAL EQUIPMENT – TECHNICAL SPECIFICATIONS****TE-10 CABLE TRAY, SUPPORTS AND CONDUIT SYSTEM****TABLE OF CONTENTS**

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TE-10 CABLE TRAY, SUPPORTS AND CONDUIT SYSTEM

TE-10.1 GENERAL DESIGN AND COORDINATION

The Contractor shall design for the power station, a complete cable tray, cable support, cable trenches and other structures as well as conduit system for all electrical power, controls, protection, alarm, indication and communication interconnection wiring, for all electrical and mechanical equipment, in the power plant including powerhouse and transformers area, prepare electrical elementary diagrams, cable and conduit schedules, and interconnection wiring diagrams for all such work; and supply, install, test and commission the complete cable way system for the interconnection wiring, and install, connect and test the grounding system for all such equipment. Outdoor cable shall be suitably installed in cable trenches.

The embedded parts for the conduit, cable tray and support systems shall be designed, furnished and installed by the Contractor. Materials to be embedded in concrete shall be provided and delivered together with necessary information (such as drawing) before concrete work period in order to coordinate with civil work.

TE-10.2 DETAILED REQUIREMENTS FOR CABLE TRAY AND CABLE SUPPORT SYSTEM

TE-10.2.1 General

The Contractor shall furnish cable tray and cable support system complete with brackets, supports, hardware and special fittings for power and control cables in the power plant including powerhouse and transformers area, shown on the drawings or as approved by the Engineer. Special fittings shall include tees, wyes, bends, crosses, dividers, reducers, dropouts, connectors and supports and all other materials required to form a complete cable tray system. Support, shall allow future installation of additional trays, where required, without disturbing the existing installation.

The Contractor in his design shall give preference to the use of cable trays through out. Where this is not feasible because of space, cable supports may be used, or conduits subject to Engineer approval.

The Contractor shall submit complete data to the Engineer for approval prior to purchase of the cable trays and appurtenances he proposes to furnish. Such data shall include drawings, construction details and a list of component parts, together with a description of each part.

TE-10.2.2 Cable Trays and Racks

Cable trays and racks shall be made of galvanized steel of suitable width, maximum six hundred (600) millimeters, with maximum one hundred (100) millimeter sides or as approved by the Engineer. Prefabricated fittings shall be used for changes in direction, elevation or size and field fabrication shall be limited to cutting straight sections for odd lengths only. Couplings and elbow plates between trays and fittings shall be firm without offset or sharp edges.

Conduits joining the tray system shall be grounded thereto. Steel trays and fittings shall be hot-dip galvanized after fabrication.

Minimum clearance between trays and walls shall be fifty (50) millimeters. Cable tray covers shall be provided for cable protection where required. Prefabricated brackets for supporting the trays and racks shall be mounted on prefabricated steel supporting structures anchored to the walls, floor or ceiling. Field installation shall be by butting or bolting. Supporting structures shall permit position adjustment of trays or racks. All steel fittings, rods, nuts and bolts shall be hot-dip galvanized or otherwise protected against corrosion adequately.

TE-10.2.3 Cable Supports

Cable supports shall be steel structures anchored to the walls, floor or ceiling or suspended from the ceiling with rods. Supporting structures shall permit a flexibility for spacing and holding on them. All fittings shall be hot-dip galvanized or otherwise adequately protected against corrosion. Cushion type cable clamps shall be provided to hold firmly the cables on the steel supports without harming the cable insulation.

The Contractor shall submit to the Engineer for approval, data and installation drawings, before furnishing and installing such cable supports. trays through out. Where this is not feasible because of space, cable supports may be used, or conduits subject to Engineer's approval. The Contractor shall submit complete data to the Engineer for approval prior to purchase of the cable trays and appurtenances he proposes to furnish. Such data shall include drawings, construction details and a list of component parts, together with a description of each part.

TE-10.3 DETAILED REQUIREMENTS FOR CONDUIT SYSTEM

TE-10.3.1 General

Conduit system shall be complete with conduits, boxes and fittings including all required hardware such as bolts, screws, hangers, concrete inserts, locknuts, clamps, bushings, couplings, pulling irons and identification tags.

Conduit system shall be preferably embedded in concrete when running in the generator floor and in the erection area, in all other areas can be either concealed or exposed subject to Engineer approval.

The Contractor shall design, furnish and install a complete conduit system required for the power and control cables in the powerhouse and transformers area.

TE-10.3.2 Rigid Metal Conduits and Fittings

Rigid metal conduits and fittings shall be used in area where there is danger of mechanical damage, such as when running exposed and up to two (2) meters above floor level, or up to cable trays.

Rigid metal conduits shall be seamless, hot-dip galvanized steel meeting the latest requirements of the IEC Standards, Fittings and covers shall be galvanized, sherardized, or

cadmium-plated, gray iron, or malleable iron castings, meeting the latest requirements of the IEC Standards.

Expansion joints shall be a standard manufactured product and designed to prevent cable damage to cables providing electrical continuity of the conduit in a manner approved by the Engineer. They shall allow a small amount of transverse as well as longitudinal movement.

TE-10.3.3 Non-Metallic Conduit and Fittings

Non-metallic conduits conforming to IEC Publication 60614-2-2 shall be used in all cases, except in areas where there is danger of mechanical damage as stated in the above paragraph. They shall in general be also used for outdoor concrete encased cable ducts. These shall be hard PVC, with standard segments and bends, Harrington couplings or approved equal and rubber ring expansion couplings. All cables in PVC conduits must have an extra conductor for grounding or be shielded with the shield properly grounded.

TE-10.3.4 Flexible Steel Conduit

These shall be hot-dip galvanized or liquid-tight flexible conduit as approved by the Engineer, and shall be used in general only for small runs near the equipment and as approved by the Engineer. Flexible steel conduit shall be complete with standard threaded couplings and other fittings.

TE-10.3.5 Metallic Outlet, Pull, Junction and Terminal Boxes

Outlet and sheet-steel pull boxes, both Cadmium or Zinc -coated and junction boxed constructed from galvanized sheet metal shall be furnished with screw-fastened covers. Gaskets shall be provided for boxes located outdoors or in damp rooms. Terminal boxes shall be equipped with 600 volt terminal blocks, channel mounted type, complete with pressure wire connectors and identification labels. Transition barriers and insulation shrouds shall be furnished for power supply wires.

TE-10.3.6 Installation of Conduits

a. General

Conduit ends shall be sealed, during installation, whenever the work is interrupted, and upon completion runs shall be sealed by the use of plugs or caps and discs. Seals shall not be removed until the conductor is pulled in. Conduits prior to conductor installation shall be cleaned and checked by pulling a wooden mandrel of the proper size through the conduit. If a permanent block is found during checking or during installation of conductors, the conduit and surrounding concrete shall be replaced without additional expense to the Owner. This cleaning has to be executed by the Contractor. All boxes and fittings shall be kept closed and free from foreign matter and moisture.

b. Metal Conduit Installation

Conduit runs shall be electrically continuous between boxes or equipment and grounded. Conduits shall be cut square with reamed ends. Threads shall be cut with approved dies. Conduit joints and threads shall be made thoroughly watertight and rustproof by means of the application of a non-insulating thread compound, such as white lead or an equal approved by the Engineer. Locknuts shall be used on both sides of slip holes to secure conduits entering boxes.

Concrete embedded conduit shall be sloped towards the drain points and rigidly supported and braced during concrete placement. In concrete the reinforcing bars will be bent, not cut, to permit passage of conduits, but cutting of holes in concrete will require prior written approval of the Engineer.

Conduit boxes shall be installed parallel with building lines and where embedded, flush with the finished surface. Conduit box covers and openings shall be easily accessible. All boxes not properly installed shall be removed and reset without additional expense to the Owner.

Conduits crossing concrete contraction or expansion joints shall be installed perpendicular to the plane of the joint with suitable expansion fittings.

Exposed conduit runs shall be in straight lines parallel to column lines, beams or walls. Offsets shall be uniform and symmetrical, obtained by use of conduit fittings, bends or boxes. Support for exposed conduit shall be at intervals of not more than 1.5 meters for up to and including twenty one (21) millimeter conduit and not more than three (3) meter intervals for twenty nine (29) millimeter conduit and over. Capped conduit and conduit terminating in boxes or fittings shall be supported approximately one hundred and fifty (150) millimeters from the terminal. U- and J-bolts shall be used for fastening conduit. These shall be galvanized or cadmium-plated. Boxes and equipment housings shall be supported independently of the conduits. Bending (by bending machine) shall not reduce the conduit internal diameter or injure protective coating. Conduit runs shall be sectionalized by pull boxes, where required, as follows :

Maximum length of run meters	Maximum number of 90 degree bends
Up to 15	3
16 to 30	2
31 to 45	1

Permanent fiber or plastic tags bearing the conduit designation number shall be attached to each end and at junction and pull boxes. Samples of the proposed tags shall be submitted for approval to the Engineer.

c. Non-Metallic Conduit Installation

Non-metallic conduits may be used in conduit system runs embedded in concrete and as otherwise specified under para 10.3.3 herein above.

Installation of non-metallic conduits shall in general satisfy the installation requirements described above for metallic conduits, as applicable, and as approved by the Engineer. Non-metallic conduits shall also be installed as required with duct runs having a minimum pitch towards drainage locations of twenty five (25) millimeters per one hundred (100) meters. Embedded conduits in ducts shall be supported on spacers at maximum intervals of one (1) meter. Spacers shall be prefabricated as recommended by the conduit manufacturer, and no makeshift spacers shall be used. Field-cut conduit shall have machine-tapered ends made with tools designed for the purpose. Direction changes exceeding 10 degrees shall be made with standard curved bends or segments. Conduit joints installed in groups shall be staggered vertically and horizontally a minimum of one hundred and fifty (150) millimeters. Conduits shall be jointed tight with a compound recommended by the conduit manufacturer.

d. Flexible Steel Conduit Installation

Where rigid conduit cannot be used conveniently, short lengths of flexible conduit may be used for connection such as to conduit boxes or motors. Standard flexible conduit fittings shall be used for connection to rigid conduits and boxes. In wet locations and where exposed to the weather, liquid-tight flexible conduit and suitable fittings shall be used.

TE-10.4 CABLE TRENCH

The Contractor shall furnish cable trench and cable support system complete with brackets, supports, hardware and special fittings for power and control cables for outdoor cable of the power plant connect to cable tray in powerhouse, shown on the drawings or as approved by the Engineer.

The cable trays shall be designed to separate the cable categories (HV, LV power and control cables) When only few of power and control cables are running, a common cable tray will be allowed with a separating barrier (divider) installed inside of the tray.

TE-10.5 MANHOLES AND HANDHOLES (if applicable)

Electrical manholes and handholes shall be constructed as shown on the Drawings or as directed by the Engineer. Top, walls, and bottom shall be composed of reinforced concrete. Walls and bottom shall be of monolithic construction. Concrete, forms, mixing, pouring and reinforcing bars shall conform to concrete for building construction, as described in these Technical Specifications. Covers shall properly watertight.

End of Chapter

TE-11 INSULATED CABLE AND FIRE BARRIERS

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TE-11 INSULATED CABLE AND FIRE BARRIERS

TE-11.1 GENERAL DESIGN AND COORDINATION

The Contractor shall design for the powerhouse, all electrical power, controls, protection, alarm, indication and communication interconnection wiring for all electrical and mechanical equipment in the powerhouse, transformers area, prepare electrical elementary diagrams, cable and conduit schedules, cable routing lists and interconnection wiring diagrams for all such work and supply, supervision of install, test and commission a complete cabling system, effectively protected by fire barriers along cableways, for the interconnection of all such equipment. The lighting and power sockets are excluded from the scope of supply. The lighting (and small power), grounding, lightning protection and fire alarm systems shall be according to TE-12 where all details are specified.

All conduits and cable trays, racks and supports for these systems will be designed, furnished and installed by the Contractor as described under TE-10 of these Technical Specifications.

The Contractor shall also design, supply, for the powerhouse, supervision of install, test and commission a fire detection system along the cableways and in fire hazard areas, as described herein and as approved by the Engineer.

TE-11.2 DETAILED REQUIREMENTS FOR INSULATED CABLES

TE-11.2.1 General

The cable installation shall include all necessary relevant materials, cable grips and wedges, cable terminators, identification tags and other miscellaneous equipment to make a complete installation ready for operation. Power and control cables shall be installed either on cable trays or in conduits. No power cables shall be allowed to run concealed in concrete and walls. Cables shall not be run exposed on walls except as approved by the Engineer.

Cables shall be of the following types:

- a. Low voltage power cables shall be 0.6/1 kV, multi or single-core, XLPE insulation, FR-PVC outer jacket, 90°C temperature rating.
- b. Control, annunciation and instrument transformer secondary wiring shall be 600/1000 volts multi-core, FR-PVC outer jacket, 70°C temperature rating.
- c. Telephone cables shall be screened twisted pair for the connections of Logic control (telecontrol - telesignalisations), and low current level (0-20mA) measures (temperature, e.t.c) and orders (e.g. closure of intake gate in case of emergency shutdown).
- d. Super shielded coaxial or fiber optic cable for serial communication if it is required as well as special underground 0.8 mm telephone cable.

Unless otherwise specified, insulation for all power and control cables up to 1000V shall be polyvinyl chloride or cross linked polyethylene, heat and moisture resisting, calculated for a maximum conductor temperature of 70°C even if such insulation allows higher conductor temperatures. The jacket of a single conductor cable inside a multi-conductor cable shall be black polyvinyl chloride meeting IEC Standards.

Insulation of telephone cables shall be shielded polyethylene with overall neoprene jacket.

Construction features and procedures for splicing and terminating for all cable and wire shall be submitted for the Engineer's approval.

TE-11.2.2 Conductors

Unless otherwise specified, these shall be high conductivity annealed copper wire. All power and control cables shall have conductor stranding comply with IEC 60228.

The conductors for control, annunciation, and instrument transformer secondary wiring shall be as follows

- a. Three conductor or five conductor cables of 2.5 square millimeter cross-sectional area for LV voltage transformers and two conductor 4 square millimeter for LV current transformers.
- b. Four-conductor cables of minimum 4 square millimeter cross-sectional area for MV current transformers and 2.5 mm² for MV voltage transformers. For these transformers, the cross-sectional area of the cables shall be determined by the Contractor in accordance with the rated burden of the transformers and the adequate accuracy of the metering and relaying system.
- c. Multi-conductor control cables shall be of minimum size 1.5 square millimeter cross-sectional area and shall a minimum of one (1) spare

TE-11.2.3 Installation of Cables

Separate cable trays or racks shall be provided for the main runs of MV cables, LV power cables and control cables. Cables shall be fastened on the cable trays at intervals of 1.5 m.

Multi conductor cables LV or DC with cross -section superior to 6 mm² shall posed in one layer and joined on cable trays. Enclosures and cabling shall be protected against rodents and other pest with appropriate means.

TE-11.2.4 Color Code

As specified in TG General Technical Specification.

TE-11.2.5 Tests

- a. Factory Inspection and Tests

The insulated power and control cables shall be completely constructed and fabricated at the factory and subject to tests in accordance with IEC Standards or other standards approved by the Engineer.

Factory inspection and tests shall be in accordance with the General Conditions.

For power and control cables with polyvinyl chloride insulation and jacket, factory tests shall include the following:

1. Tests on Samples
2. Electrical Tests on Entire Lengths

b. Field Tests

After installation, all insulated power cables shall be tested for insulation resistance. Field tests shall be made in accordance with the IEC Standards.

TE-11.2.6 Cable Reels

Cable shall be transported on reels plainly marked in a water-proof manner with contract number, item number, length shipped, length ordered, number and size of conductors and voltage rating.

TE-11.3 FIRE BARRIERS FOR CABLEWAYS

The powerhouse shall be equipped with the following:

Fire barriers shall seal all major wall and floor passages and openings under all electrical boards as approved by the Engineer for the sectioning of cable routes and cable tunnels and trenches to prevent fire and smoke from spreading from one room or area to another.

In long cable trenches, fire barriers shall be provided at their two ends. Fire barriers shall consist of seal bags made of fibre glass cloth filled with mineral fibre, incombustible components water expansion agents and fire retardant additives.

Acceptable also fire barriers will be that of penetration seals which consist of mineral wool panels and mastic used as a joint filler and sealer.

A surface coating will be applied to the cables near the barrier (1.5 m either side of it). This coating consists of a water based thermoplastic resin with various retardant and inorganic fibres.

Other equal barriers with at least 90 minutes fire resistance rating, shall be accepted after the approval by Engineer.

End of Chapter

TE-12 BALANCE OF PLANTS (BOPs)

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TE-12 BALANCE OF PLANTS (BOPs)

TE-12.1 GENERAL

TE-12.1.1 Scope

This Chapter covers the requirements for the design, supply, installation and testing of:

- Lighting and small power.
- Embedded and buried electrical grounding.
- Lightning protection system for power station building.
- Fire alarm system.

TE-12.1.2 Standards

The works will be in accordance with the applicable Thai Industrial Standards (TIS) and with the specifically referenced Codes and Standards published by the following organization:

ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
NEC	National Electrical Code (USA)
NEMA	National Electrical Manufacturers Association
UL	Underwriter's Laboratories

TE-12.1.3 Submittals

Drawings, calculations, test reports and literature pertaining to each item of material to be supplied shall be submitted for approval not later than 6 weeks prior to commencement of the work. In addition to the above, the following specific drawings and design data shall be submitted:

- Manufacturer's drawing with technical details, design data, installation drawings and instructions for equipment;
- General layout drawings showing location of equipment and routing of distribution lines;
- Schematic and wiring diagrams and single line diagrams;

- Plans, sections and details of equipment foundation, roof over equipment, roof supports and fencing requirements;
- Shop drawings, as applicable;
- Samples, as directed.

Additional submittals shall be as indicated in the detailed Specifications for each of the work items covered by this Chapter.

TE-12.1.4 Power Supply

400/230 V AC power supply will be made available from the common AC auxiliary panel board.

230 V AC essential power supply will be made available from the 230 V AC distribution board of UPS system.

TE-12.1.5 General Electrical Specification

TE-12.1.5.1 Rules and Regulations

All equipment and works under this Specification shall comply with the requirements of the Thai Industrial Standard, National Electrical Code, and all local ordinances. The Contractor shall file the required notices with and obtain the required permits from any authority having jurisdiction over such permits and obtain and pay for all permits required.

TE-12.1.5.2 Disconnect Switches (not applicable)

TE-12.1.5.3 Sleeves and Forms for Openings

Sleeves and slots for piping panel rating floors, walls, partitions, etc., shall be supplied and installed prior to placement of concrete.

TE-12.1.5.4 Raceways and Fittings

a. Materials

Rigid Conduit

Steel Conduit shall be hot-dipped galvanized, seamless type and shall be bituminous coated, when buried underground.

Flexible Conduit Couplings and Fittings

Liquid-tight, flexible metal conduit shall have interlocked, galvanized steel core, with abrasion resistant, liquid-tight, PVC covering.

Fittings used with flexible conduit shall be of the screw-in type.

Boxes and Fittings

Pressed steel boxes shall be hot-dipped galvanized.

Cast iron boxes and fittings shall be galvanized with cast galvanized covers and corrosion-proof screws.

Conduit Mounting Equipment

Hangers, rods, backplates, beam clamps, etc., shall be hot-dipped galvanized iron or steel.

b. Installation

No conduit smaller than 16 mm electrical trade size shall be used. No conduit shall have more than three 90° bends in any one run. Pull boxes shall be provided as required or directed.

No wire shall be pulled into the conduit system until it is complete in all details: in the case of concealed work, until rough plastering or masonry has been completed, and in the case of exposed work, until the conduit system has been completed in every detail.

Ends of conduits shall be tightly plugged to exclude dust and moisture during construction.

Conduits and fittings on exposed work shall be secured by means of metal clips and back plates.

Conduit supports shall be spaced at 3.0 m intervals or less, as required to obtain rigid construction.

Single conduits shall be supported by means of one-hole pipe clamps in combination with one-screw back plates to raise conduits from the surface. Multiple runs of conduits shall be supported on hangers with steel horizontal members and threaded hanger rods. Rods shall be not less than 9 mm diameter.

Conduit hangers shall be attached to structural steel by means of beam or channel clamps. Where attached to concrete surfaces, concrete inserts of the spot-type shall be provided.

Conduit on exposed work shall be run at right angles to, and parallel with the surrounding wall and shall conform to the form of the ceiling. No diagonal runs will be allowed. Bends in parallel conduit runs shall be concentric. Conduit shall run perfectly straight and true.

Conduit terminating in pressed steel boxes shall have double lockouts and bushings.

Conduit terminating in gasketed enclosures shall be terminated with conduit hubs.

Liquid-tight flexible metal conduit shall be used for equipment where vibration is present.

Expansion and deflection fittings shall be used where conduits cross building expansion joints.

Pressed steel boxes shall be used for concealed work. Exposed boxes and fittings shall be cast metal.

c. **Pull Boxes and Junction Boxes**

A pull box is defined as a box installed in a conduit system through which wires and cables are pulled without cross-connections between the conductors. Wire and cable pulled through a pull box shall have a one-turn coil left in the box. Splices in through runs are not permitted. Wire and cable shall be laced or tied in groups according to their conduit runs.

A junction box is defined as a box installed in a conduit system in which cross-connections are made between conductors. Pull boxes and junction boxes shall be sized and constructed in accordance with the National Electric Code.

Junction boxes shall contain terminal strips mounted on stand-off blocks not less than 15 mm high. Each terminal point shall have an insulated barrier between it and adjacent points, and each point shall have provision to connect two wires with separate screws. Terminal strips shall be rated at 600 V ac and 30 A. All wires 4.0 mm² or smaller entering a junction box shall be terminated on a terminal strip and any necessary cross-connections shall be made by multiple connections to the same point or by means of jumper wires. Junction boxes may contain more than one terminal strip and each terminal point and each strip shall be uniquely numbered. All wires 4.0 mm² or smaller shall be connected to the terminal strip points by means of ring lugs on the wire ends. Power wires and cables larger than 4.0 mm² may pass through a junction without connecting to a terminal strip; however if such wires and cables require splicing in the boxes, they be connected to adequately sized terminal strips.

TE-12.1.5.5 Wires and Cables

a. **Samples**

Samples of proposed wire shall be submitted for approval. Each sample shall have the voltage and the size and type of insulation stenciled on the jacket.

b. **Materials**

Wire and cables shall be of annealed, 98 percent conductivity, soft-drawn copper.

Conductors, 6 mm² and larger sizes, shall be stranded.

c. Wire and Cable

Cable used for aerial lead-in lines for lighting, control circuits and power supply shall be 750 V, 75° C, PVC insulated, single core, THW Type.

Underground cable used for lighting, power supply to anode junction boxes, transformers and rectifiers shall be 750 V, 60° C, PVC insulated and double-sheathed round NYY Type.

Underground cable used for control and indication circuit shall be 600 V, 60° C, PVC insulated and sheathed control cable, CVV Type.

No wire smaller than 2.5 mm² shall be used for lighting and power circuits.

For control and signal circuits, no wire smaller than 0.75 mm² shall be used.

d. Installation

Conductors shall be carefully handled to avoid kinks or damage to insulation.

Approved lubricants shall be used to facilitate wire pulling.

Type THW wire shall not be used underground.

TE-12.1.5.6 Panelboards

a. Standards

Panelboards shall be in accordance with the Underwriters' Laboratories, "Standard for Panelboards" and "Standard for Cabinets and Boxes". Panelboards shall also comply with the NEMA Standard for Panelboards and with the National Electrical Code.

b. Construction

Interiors

Interiors shall be completely factory-assembled with circuit breakers, wire connectors, etc. Wire connectors, except screw terminals, shall be suitable for copper of the sizes indicated.

Interiors shall be designed such that circuit breakers can be replaced without disturbing adjacent units and without removing main bus connectors and shall be designed such that circuits may be changed without machining, drilling, or tapping.

Branch circuits shall be arranged using double row construction, except when narrow column panels are indicated. Branch circuits shall be numbered by the manufacturer.

Nameplates shall be provided, listing panel type, number of circuit breakers, and ratings.

Buses

Busbars for mains shall be of copper. Full size neutral bars shall be included. Busbar taps for panels with single pole branches shall be arranged for sequence phasing of branch circuit devices. Bus shall be braced throughout to conform to industry standards for short circuit stresses in panelboards. Phase busing shall be full-height without reduction. Cross-connectors shall be copper.

Neutral bus shall have suitable lugs for each outgoing feeder requiring a neutral connection.

Spaces for future circuit breakers shall be bussed for the maximum number of devices that may be required to be fitted.

Boxes

Boxes shall be galvanized 24-gauge steel having multiple knock-outs. Surface-mounted boxes be painted to match the trim. Boxes shall be of sufficient size to provide a minimum gutter space of 100 mm on all sides.

Trim

Hinged doors covering circuit breaker handles shall be included in panel trims.

Doors shall have semi-flush type cylinder lock and catch, except that doors over 1.20 m in height shall have a vault handle and 3-point catch complete with lock, arranged to fasten door at top, bottom, and center. Door hinges shall be concealed. Two keys shall be supplied for each lock. All locks shall be keyed alike; directory frame and card, having a transparent cover, shall be furnished for each door.

Trims shall be fabricated from 24-gauge sheet steel

Exterior and interior steel surfaces of panelboards shall be properly cleaned and finished with gray paint over a rust-inhibiting coating. Finish paint shall be of a type to which field applied paint will adhere.

Trims for flush panels shall overlap the box by at least 20 mm all around. Surface trims shall have the same width and height as the box. Trims shall be fastened with quarter-turn clamps.

Circuit breakers

Panelboards shall be equipped with circuit breakers with frame size and trip settings, to be shown on Drawings, to be submitted by the Contractor for approval.

Circuit breakers shall be molded case, bolted-in type.

c. Installation

Boxes for surface-mounted panelboards shall be mounted such that there is at least 15 mm air space between the box and the wall.

TE-12.1.5.7 Circuit Schedules

Schedules shall be provided for the power and lighting distribution panels, indicating breaker sizes and the equipment connected in each circuit. Schedules shall be on cardboard, varnished and mounted in frames under clear plastic and installed inside panel doors.

TE-12.1.5.8 Tagging

Cable markers shall be provided to identify control wires to the switchgear, motor control centers, control panels and local control components in accordance with the Drawings.

TE-12.1.6 Testing

On completion of the work, all circuits and electrical equipment shall be tested for grounds, short circuit and for proper functioning.

All necessary tests required by the Engineer, local authorities or any authorized inspector shall be carried out and the inspector's certificates approving the installation submitted to the Engineer. Upon completion of the works, all test for services and equipment have been carried out and that all faults have been corrected to ensure operation in accordance with the Specifications and the manufacturers' recommendations shall be submitted.

Required tests shall include, but not be limited to, the following:

- Continuity test of low voltage circuits,
- Energizing of low voltage circuits,
- Verification of operation of meters, relays, instruments, alarms and trips,
- Functional testing of equipment,
- Ground resistance.

The installations shall be left clear of all unspecified grounds and short circuits and shall be properly working to the full satisfaction of the Engineer.

The Engineer shall be given sufficient notice prior to any tests, so that his representative may be present.

Wiring for each system and/or part of a system shall be checked carefully to ascertain that the system functions properly as indicated by wiring diagrams, schematic diagrams, descriptions of operation, etc. Alarm and control devices shall be operated manually to check whether their operation during normal operating conditions causes the proper effect.

When electrical tests have been completed, operational tests shall be performed and final adjustments made.

Equipment shall not be energized until all safety and protective devices are properly set and thoroughly tested for proper and accurate operation. No equipment shall be energized until all ground connections have been made and tested.

TE-12.1.7 Service Condition

TE-12.1.7.1 Climatic Condition

All equipment shall be designed for the following service condition:

- | | | | |
|----|--------------------------|----|-------|
| a. | Max. ambient temperature | | |
| | - indoor | °C | 40 |
| | - outdoor | °C | 45 |
| b. | Max. relative humidity | % | 100 % |

TE-12.2 LIGHTING AND SMALL POWER

TE-12.2.1 General

All interior and exterior lightings shall maintain illumination levels using Light Emitting Diode (LED) lamps.

LED tube lamps shall be used in combination with industrial fixtures for illumination in areas without suspended ceilings in the Building.

The control room/office lighting consists of general area, control console/panel, and emergency lighting. The control room shall be illuminated with commercial LED tube lamps with parabolic reflector are located to direct the light precisely and with a minimum of glare.

LED high bay lamps shall be used with industrial lighting fixtures for illumination of machine hall.

The emergency lighting unit with integral batteries and LED bulb lamps shall be used for illumination as a means of egress for the power house and for emergency lighting in the areas

of control panels, motor control centers, battery room, inverter and battery charger. The emergency lighting unit normally shall be “off ” and will be turned “on” automatically upon loss of the station ac service.

The emergency exit sign with lamp shall be provided at suitable position with its own distribution panel and fed power from 230 V ac UPS’s distribution board furnished by the Contractor.

Convenience outlet receptacles shall be installed 300 mm above the floor in areas that have suspended ceilings, and 900 mm above the floor in areas that do not have ceiling systems. Light switches shall be installed 1,300 mm above the floor.

All equipment installed in Battery Room shall be acid-resistant, weather-proof type.

TE-12.2.2 Operating Conditions

Table 1 lists the maintained illumination levels and light sources for areas in the buildings. The maintained illumination level is the design Lux level which will exist at the end of lamp life and with the light fixtures in need of being cleaned. Initial illumination levels shall be higher than maintained levels.

Operation of the illumination system is dependent upon the vision requirements of the building operating personnel. The general lighting shall be manually switched on and off by circuit breakers at suitable location approved by the Engineer. The lighting for enclosed areas within the buildings shall be manually switched on and off at local light switches near personnel entrance doors. Personnel outdoor entrance door lighting shall be switched with photoelectric controllers and local light switches in series with the photoelectric controller. Emergency lighting units with integral batteries will be normally off and turned on upon loss of the ac normal lighting power supply.

The exterior lighting system shall operate between the hours of sunset and sunrise. The exterior lighting system shall also allow for manual off control during the hours when task illumination is not required.

TE-12.2.3 Physical Constraints

Light fixtures shall be installed at a minimum height of 2,500 mm above the floor to provide an unobstructed way of exit travel from any point in the buildings.

Table 1
Illumination Levels and Light Sources

Area	Working Level Maintained	Light Source
	Lux	
<u>Interior Location</u>		
MV Switchgear, LV Switchgear, Motor Control Centers (if applicable), AC/DC Distribution Board (Electrical Room)	300	LED tube
Generator & Turbine Floor,	300	LED tube
Erection Bay, High Bay (if applicable)	300	LED high bay
Control Room / Offices	500	LED tube
Valve Chamber, Guard House, Locker Rooms, Toilets	200	LED tube
Battery Room	300	LED tube
Emergency Lighting	150	LED bulb
Egress and Emergency Lighting		
Stairways	10	LED bulb
Exits	10	LED bulb
Exit Light***	50	LED bulb
<u>Exterior Location</u>		
Building Entrances	20	LED street light
Entrances	20	LED street light
Platforms / Transformer Yard	50	LED street light
Roadways / parking Area	5	LED street light

*** Exit lights shall be located in accordance with NFPA 101.

TE-12.2.4 Design Conditions and Technical Requirements

TE-12.2.4.1 Design Data

- a. According to TE 12.1.7 Service Condition
- b. Illumination levels

The illumination system shall be designed for illumination levels as shown in Table 1 in the lighting system description. These illumination levels are operation values. For new installations, the values in Table 1 shall be increased by 25. In addition, the shape of equipment in the specific room shall be taken into account. The average illumination level for each room shall be measured at a height of 1 m above the floor level and normally used work places.

- c. Voltage Drop.

Voltage drop at any point on the circuit shall not exceed 3%.

TE-12.2.4.2 Instruction for Installation

- a. Grounding.

Grounding shall be provided for the safety of personal. For details, reference is made to TE-12.3. Every electrical appliance or equipment and all installation parts of metal shall be earthed to the DP's supply grounding. The cross-sectional area of the grounding wire shall be the same as the phase and neutral wires of the respective circuit.

- b. Types of Installations

1. General direction for lighting Installations

Rooms must have a work illumination switchable by centralized switches, and a passage illumination switchable at each door, entrance and exit.

2. Flush mouted installations

The flush mounted installation shall comply with the following:

- Degree of protection IP3X

This type of installation shall be applied for:

- Offices/control room and switchgear rooms, general corridor and staircases, toilets, etc.

3. Surface mounted Installations

The surface mounted installations shall comply with the following:

- Degree of protection shall be used according to the purpose of the room and the climatic conditions.

This type of installation shall be applied for the majority of indoor and outdoor installations. Where several cables are running along the same routing, a large diameter conduit or a cable duct shall be used. For concrete staircases the installations shall be made in a convenient design, e.g., with a small hard PVC cable duct.

c. Selection of Material

All material for the installation shall be suitable for their particular application. IEC 60529 shall be used for determination of the degree of protection IP. It shall also be considered that the material to be selected meet the following conditions where applicable:

- Normal resistant conditions
- Special warm resistant conditions
- Special corrosion resistant conditions
- Special explosion resistant conditions
- Special weather-proof conditions

d. Socket outlets servicing

Each room shall have as a minimum, one single-phase socket outlet of 250 V/10 A. In control and switchgear rooms, etc., there shall be a socket outlet every 2 - 4 m. In machine room, there shall be a socket outlet (hazardous area) for every 15 - 20 m, so that all points are accessible with a reasonable length of cable. All technical rooms such as machine room, maintenance shop, shall have one or more three-phase socket outlets of 400 V/30 A in addition to the single outlets.

e. Suspended luminaires

If the fixing of luminaires on the ceiling is not possible or the room is higher than 3.0 m, luminaires shall be suspended with steel wires or chains. LED tube luminaires mounted on suspension metal rod which carries the wiring, is also acceptable.

TE-12.2.4.3 Material

a. Luminaires

Lighting fittings shall be complete with lamp holders, auxiliary apparatus and wiring. The insulation of the internal wiring shall be such as to withstand without deterioration the highest temperature likely to be experienced in service.

The delivery shall include all brackets, support and fixings devices, etc, which are required to make a complete installation.

All fittings shall be complete with LED lamps and integral control gear of high power factor which shall not cause objectionable noise certified by TIS 1995-2551. All LED lamps shall be manufactured in accordance with relevant IEC standards.

All screw type lamps shall have Edison screw E27. In dry rooms (up to 200 lx) open type lamps shall be used. In rooms with more than 200 lx, lamps with shade screens shall be used. In fuel oil vapor atmospheres (e.g. in the pump area), luminaires shall have a degree of protection suitable for the hazardous area. If liable to damage, the luminaires shall be protected with suitable grating.

In large rooms and rooms with rotating machine parts the luminaires must be evenly distributed over the 3-phase/4-wire system to avoid the stroboscopic effect.

LED bulb luminaires (instead of incandescent luminaires)

This luminaire type is applicable only for small rooms, where the light is frequently switched, such as toilets, cleaning rooms, etc. and for DC emergency lighting. The covers for emergency luminaires at way-outs shall be marked with EXIT information.

LED tube luminaires (instead of fluorescent luminaires)

This luminaire is the most acceptable type of lighting fixture in the plant area, and shall be applied compatible with:

Normal : T8 fluorescent luminaires (Electronic), 1x36 w, 2x36 w.
T8 fluorescent luminaires (Electronic), 1x18 w, 2x18 w.

For buildings or rooms up to 5 m high, mounting trunking or hangers shall be used so that lighting fixtures can be mounted in continuous lines.

LED high bay luminaires

For the lighting of indoor industrial areas with a ceiling height of 6 m and more, high bay luminaires with reflectors shall be installed. Reflectors are required for lamps. Anodized aluminum semi-intensive reflectors shall be used to ensure the highest possible illumination for important high mounted applications.

The main features shall be:

- Modern styling and materials
- Luminaires with low overall height
- Suitable for high ambient temperatures

- Glass dust cover available for humid and dusty environments
- Universal mounting system for suspension with chains, bracket or suspension tube
- Control gear for integral and separate mounting

LED street light luminaires (instead of high pressure sodium luminaires)

The outdoor illumination for plant areas and connecting roads shall be of weather-proof luminaires (IP65) with holders. These shall fulfill the following description:

- Die-cast aluminium housing and clear diffuser
- All electronic parts shall be protected from moisture, dust, vibration, overcurrent, overvoltage (lightning & surge) short-circuit.
- Four toe-in angle adjustments:
5° - 10° - 15° - 20° towards the road axis, standard position 15°
- Suitable for mounting on mast arms or on mast-tops.
- One-piece optical unit consisting of lamp holder, toe-in angle bracket, reflector plate and mirrors (if any), easily removable for servicing purposes
- One-piece electrical unit comprising all electrical parts, hence easy maintenance and replacement
- After the clips have been unfastened, the diffuser remains hinged to the housing.

b. Switches

Depending on type of installation and ambient conditions the following type of switches and push buttons shall be used:

- Flush type, plastic front housing
- Surface type, weather-proof plastic housing
- Surface type, heavy duty weather-proof metallic housing

Each room shall be switched separately. If necessary, rooms shall be divided into separate switch groups.

c. Photo-Electric Cell

The photo-electric cell shall switch on the outdoor illumination when the illumination level falls below 20/30 lx and switch off the illumination when the level reaches a value of 60/80 lx. The cell shall be of the cadmium sulfide type for outdoor installation. The rating of the cells shall be suitable to energize the respective contractor coil.

d. Socket outlets

Single Phase socket outlets

Socket outlets for use with domestic type apparatus shall be of duplex, universal 250 V/16 A, 3-pin type, (1-phase, 1 neutral and 1 ground) Panasonic WEG 1592K or equivalent. Depending on type of installation and ambient conditions, the following type of socket outlets shall be used:

- Flush type, plastic front housing
- Surface type, weather-proof, plastic housing
- Surface type, heavy duty, weather-proof metallic housing with metallic hinged lid

Three-Phase socket outlets

Socket outlets for use with tool type apparatus shall be of 400 V, 30 A, and 5-pin type, (3-phase, 1 neutral and 1 ground). All socket outlets shall be surface type, heavy duty, weather-proof metallic front housing with metallic hinged lid.

TE-12.2.4.4 Distribution Panels (DP's)

Buildings with several distribution panels can be fed from a building main distribution panel (MDB).

a. Panel design

Panel shall comply with the following requirements:

- Sheet steel construction with hinged front doors, wall mounted, sheet steel not less than 1.6 mm thick
- Degree of protection IP3x
- Door lockable, but without use of a key
- All equipment accessible only from the front
- Removable transparent cover plate with operation details of the equipment

Cable and/or pipe entries shall be from top for wall mounting panels

All panels shall be provided with labels (outside and inside).

Each distribution panel shall be equipped with at least 15%, but not less than 2 spare feeders. Furthermore, space for additional 20% feeders shall be available for easy extension in future.

b. Bus bars and internal wiring

The buses shall be copper. The panel shall be provide with separate neutral and earthing bars. The bus and breaker shall be arranged so that any or all breakers can be removed without disturbing any other breakers even it the bus is energized.

AC. normal supply system, 3-phase, 4-wire, 400/230 V, 50 Hz (normal lighting and socket outlets). All panels shall be designed for an initial symmetrical 3-phase short circuit current minimum of 14 kA_{rms} for the normal AC systems. The designations of the bus bars shall be as follows:

The internal wiring of the DP's shall comply with the following requirements:

- Wires shall be of single core copper conductors with PVC insulation suitable for max. conductor temperature of not less than 75°C.
- All wiring shall be laid in wiring troughs made of PVC. Space must be available for future addition of at least 20 % wires.
- No splicing shall be permitted in wiring.
- Wires shall be provided at both ends with detachable numbered ferrules:
 - Number at terminal side same as number of terminal block
 - Number at equipment side same as terminal number of equipment

c. Alarm signals.

In each distribution panel (DP) only one common alarm shall be provided for remote alarm annunciation of:

- Miniature circuit breakers trips
- Earth leakage protection breaker trips
- Thermal overload relays

TE-12.2.4.5 Tests

a. Insulation tests

The complete illumination system and small power shall be tested prior to energizing, using a 500 V megger, applied for 1 min. The insulation value shall not be below 250 kohm measured between phase- to-phase and phase-to-ground. The tests shall be performed by the Contractor and shall be witnessed and approved by the Engineer.

b. Final commissioning tests

The complete illumination system and small power shall be tested 48 hrs continuously for completeness and serviceability by the Contractor and shall be witnessed and approved by the Engineer.

TE-12.3 GROUNDING

TE-12.3.1 General

TE-12.3.1.1 Scope

Equipment grounding, other than grounding of peripheral metal parts, such as steel doors, metal pipes and fences, shall be supplied by the Contractor to ensure that the necessary pigtails are properly secured.

TE-12.3.1.2 References

The following Standard is referenced in this Section :

IEEE 80 Safety on Grounding of ac Substations

TE-12.3.1.3 Definitions

The following definitions apply in this Section :

- a. System grounding : grounding of neutral points of generator, generator transformer and station service transformers, neutral buses in switchgear and boards;
- b. Protective grounding : connecting of metallic parts to ground to ensure safety of personnel;
- c. Surge protection grounding : connecting of ground terminals of all surge arresters and surge absorbers.

TE-12.3.1.4 Submissions

The following documentation shall be submitted for approval :

- a. Design calculations for the grounding system for Power plant, including the values of safe and calculated values of the touch and step potentials;
- b. Test reports for the actual values of the grounding resistance and the touch and step potentials.

TE-12.3.2 Products

TE-12.3.2.1 Design Requirements

- a. Design Data

Grids shall be designed for maximum fault duration of 1 second as specified in TE-7.1.2 rated short-time withstand current 1 second short circuit duration. The soil resistivity measurement shall be performed by the Contractor, shall be verified by actual site measurement and being submitted for approval.

b. Grounding Resistance

Grids shall be designed such that the overall resistance of the grounding grid is within 1 ohm.

c. Permissible Touch and Step Voltages

The layout of the grounding system shall be such that personnel are not endangered during a fault following potential rise of the grid above remote ground.

Touch and step voltages shall be maintained within acceptable limits by a combination of the following measures:

- Low grounding resistance of the grounding system;
- Potential control by means of potential gradient control conductors suitably spaced, buried in the soil and concrete.

d. Grounding Conductors

Embedded grounding conductors, making up the grounding system, shall be of bare stranded copper.

Conductor cross-section area shall be such that conductor temperature will not exceed the fusing limit of the grid, but not less than 95 mm²

TE-12.3.2.2 Layout of Grounding System

a. Embedded Grounding Conductor

Bare stranded copper conductor size shall be designed to meet temperature rise and fault current conditions, but shall not be less than 95 mm²

Grounding conductors shall be embedded in the concrete floor along inside walls of buildings and around outdoor substations, to form closed loops.

Loops shall be provided at every floor of the building.

Interconnection of loops at each floor shall be by means of not less than 4 vertical connectors of the same conductor size as the main grid conductor.

If so required, conductors shall be passed through walls by way of PVC pipe embedded in the wall approximately 300 mm above floor level. Pipe ends shall be plugged with an approved mastic, following conductor installation.

Each section of embedded grounding conductor shall be continuous and without splices or kinks. Care shall be taken to ensure that no strands are broken, and that no damage occurs during concrete placement or other work.

b. Steel Reinforcement in Concrete

Steel reinforcement in concrete in structures may be adapted to provide internal mesh loops where practicable to control potential gradients, by making them electrically continuous at joints.

The control potential gradients at various floors, dummy galvanized reinforcing bars may be used as internal horizontal and cross conductors within the embedded copper grid at each concrete floor. Dummy galvanized rebars, if so employed, shall be welded together at approved spacing, to form a meshed grid or cage.

The internal meshed grid so formed at each floor shall be cadwelded to the peripheral grounding copper conductor of the grid on each floor.

c. Grounding Rods

Rods shall be of copper-clad steel of 20 mm diameter and unit length not less than 3 m.

d. Pigtail Connections

Grounding mesh conductors, 1.5 m. in length, bare conductor size 95 mm², shall be brought out as pigtails above the surface of the concrete for terminations to the Equipment. The exposed lengths shall be bound to prevent unraveling, and shall be protected at all times against damage.

The equipment supplied under this contract shall be connected to system ground through pigtail connections.

e. Grounding Connections

Equipment to be grounded shall be connected to grounding electrodes or to grounding conductors as follows :

- i) Connections of steel to steel shall be by welding,
- ii) Connections of copper to copper :
 - Below ground by exothermic method (cadweld),
 - Above ground by bolting (clamps).
- iii) Connections of steel to copper shall be by cadweld.

After making the connection, welds shall receive a bitumen coating of 2 mm minimum thickness.

- iv) Connections of conductors to Equipment shall be by bolting.

TE-12.3.2.3 Grounding of Miscellaneous Metalwork

a. Steel Doors

Steel door frames shall be connected to grounding conductors by 10 mm² copper conductors. Flexible copper connections of the same size shall be provided between door frames and panels.

b. Security Fences

Fences shall be connected to grounding electrodes at a spacing not less than 15 m, by means of 50 mm² grounding conductors.

Outside of each security fence, a 10 mm² potential grading copper conductor shall be buried at a depth not less than 0.5 m and at a distance of 1.2 m from the fence. Such conductors shall be connected to the main grounding mesh at intervals of 15 m.

TE-12.3.3 Execution

TE-12.3.3.1 Installation

Materials and equipment necessary to provide a complete and continuous grounding system shall be installed in accordance with the following requirements:

- a. Ground equipment and other metalwork, connected to the ground grid as specified in TE-12.3.2 above,
- b. Prior to making connections, ensure that contact surfaces are clean and free of non-conducting materials,
- c. Use approved methods and materials to prevent dissimilar metals from being in contact,
- d. Install buried ground wire slack between points of connection,
- e. Install buried ground wire not less than 500 mm below building and transformer foundation,
- f. Install grounding cable tight against building surfaces and parallel to the building lines when exposed,
- g. Clip exposed grounding cables to supports by means of a grounding connectors spaced at intervals no greater than 750 mm,
- h. Supply and install ground electrode test boxes within transformer fences,

- i. On completion of work, test grounding systems for proper functioning and compliance with requirement that the overall ground resistance of the interconnected grid shall not be more than 1 ohm.
- j. Provide recorded test results along with the following :
 - Sketch of typical test connections,
 - Weather conditions on day(s) of testing,
 - Test values.

Tests shall be made only after at least 5 consecutive days of dry weather.

TE-12.3.3.2 Measurement of Touch and Step Voltages

Measurements shall be made at random after completion of the grounding installation.

The touch and step voltages shall be within the limits specified above in Paragraph 12.3.2

The voltmeter internal resistance shall be greater than 1 Ohm.

Where the permissible touch and step voltages are exceeded, additional potential grounding conductors shall be installed.

TE-12.4 LIGHTNING PROTECTION SYSTEM

TE-12.4.1 Scope

This Section covers the requirements of design, supply and installation a complete lightning protection system for all exposed buildings.

TE-12.4.2 System Design

The system shall consist of air terminals, roof and down conductors (main conductors) and branch conductors, grounding and bonding of equipment. The system shall be totally exposed as required to meet the approval of the Engineer and specifications for the type of building or structure.

Air terminals shall consist of solid copper rods with a tapered point 0.16 meter in height, space at intervals not less exceeding 7.6 meter. Minimum height of air terminals shall be such as to bring the tip not less than 0.254 meter above the object to be protected, with spacing of less than 7.6 meter recommended.

The main conductors shall be copper cable, of the grade ordinarily required for industrial electrical work normally designated as being 98 percent conductivity when annealed, and shall be of a size not less than 50 mm².

Branch conductors used for bonding equipment shall be copper cable not less than 50 mm².

The contractor shall submit to the Engineer document verifying the zone of protection by the lightning protection system covers all structures in the plant.

Other design criteria which is not specified shall meet the minimum requirement of UL96, 96A

TE-12.4.3 Grounding

Each downlead cable shall terminate at a ground rod. Ground rods installed for the electrical system shall have a common ground with the lightning protection system.

TE-12.4.4 Materials

Material used in the installation of the lightning protection system shall be as approved by the Engineer. Prior to making the installation, a complete list of materials, catalog data and shop drawings shall be submitted for approval. In the event that any items of material or equipment contained in the schedule fail to comply with the specification requirements, such items shall be rejected.

The system furnished under this Specification shall be the product of a manufacturer regularly engaged in the production of lightning protection system and shall be the manufacturer's latest designs.

TE-12.5 FIRE ALARM SYSTEM

TE-12.5.1 Scope

The Contractor shall design, manufacture, shop test, supply, installation and commissioning for detection systems. The Contractor shall prepare and submit shop drawings that show all the necessary details to the Engineer for approval.

Complete detection systems, including manual alarm station (manual pull stations), strobe and horn, controls, wiring, conduit, fire detection devices, and instrumentation as required for complete systems shall be furnished.

Supervisory control panels as specified herein shall be furnished. These panels shall provide supervision and control of the systems and annunciation of fire and trouble alarms.

The detector system shall be fed power from 230 V ac UPS's distribution board furnished by the Contractor.

TE-12.5.2 Reference

Fire alarm system design, materials, testing, inspection, and documentation shall conform to applicable portions of the following adopted and published codes and standards, except where more stringent requirements are specified herein:

National Fire Protection Association (NFPA) Standards and Recommended Practices:

- No.70 - National Electrical Code
- No.72 - National Fire Alarm Code
- No.90A - Air Conditioning and Ventilation Systems

Factory Mutual Standards (FM).

TE-12.5.3 Detection Arrangement

Detectors for actuation of suppression, and independent detection systems shall be arranged in accordance with NFPA 72.

Heat detectors shall be provided with a heat collector when specified herein and as required by the Contractor's design.

Manual alarm station shall be located through the entire building. The station shall be installed and alarm accordance with NFPA 72, and other applicable code or standard.

The fire alarm systems shall be furnished complete with the following equipment:

- Supervisory control panel with distinctive trouble and alarm signals a specified in this section under TE-12.5.4.
- Strobe and horn.
- Manual alarm station. (Manual pull stations).
- Heat and smoke detection system.
- Connecting wiring and raceway for all electrical devices and detectors.

TE-12.5.3.1 Smoke Detector

Smoke detector spacing shall be in accordance with NFPA 72 and the manufacturer's guidelines.

The detectors shall employ light emitting diodes for indicating normal, unstable, and alarm conditions. The detectors shall be FM approved, shall automatically reset when the chambers are cleared of smoke, and shall have passed UL 268.

Spacing and location of smoke detectors shall take into account the airflow's in the protected area, ceiling heights, ceiling construction such as beams or beam pockets, and smoke stratification. Detectors shall not be located close to areas of high airflow.

TE-12.5.3.2 Rate of Rise Heat Detector

The rate of rise heat detectors are of type to detect fire by temperature rise due to fire at rate including predetermined value.

The rate of rise heat detectors shall operate within 30 sec under 85 cm/sec air stream of which temperature is higher than room temperatures by 30 degrees Celsius, and shall operate within 1 minute under 60 cm/sec air stream of which temperature is higher than room temperature by 15 degrees Celsius.

TE-12.5.3.3 Fixed Temperature Heat Detector

The fixed temperature heat detectors are of type to detect fire at a predetermined level.

The fixed temperature heat detectors shall operate within 2 minutes under 1 m/sec air stream of which temperature is 87.5 degrees Celsius, and shall not operate within 30 minutes under 1 m/sec air stream of which temperature is 60 degrees Celsius.

TE-12.5.3.4 Manual Alarm Station

Manual alarm station shall be for sending a fire alarm signal to the control panel by operating the push button after breaching the protection cover of synthetic resin, and shall be equipped with a lamp to be lit for confirmation of receipt of the signal at the control panel..

TE-12.5.4 Supervisory Control Panels

TE-12.5.4.1 Enclosures

Enclosures for each panel shall meet the requirements of NEMA 4 unless mounted in a hazardous classified area. Internal devices shall be factory wired to terminal blocks conveniently located either on the back or bottom of the panel.

TE-12.5.4.2 System Design Functions

Each supervisory control panel shall continuously monitor its associated fire detection or suppression system (or systems).

The following distinctive alarms shall be provided at the panel:

Alarm Condition	Source	Type of Alarm
Fire (heat or smoke detected)	Heat and smoke detector	Fire
Detector circuit trouble	Open or ground in Detector wiring (Style D)	Trouble
Strobe and horn Circuit trouble	Open or ground in wiring to bell	

	(Style Y)	
Loss of primary power at panel/ battery in use	Panel	Trouble
Battery voltage Low battery	Low voltage	Trouble
Battery short, Charger, or Wiring trouble	Open or ground in circuits (Style B)	Trouble
System normal	Panel	N/A
Lamp test	N/A	Switch
Acknowledge	N/A	Switch
System reset	N/A	Switch

TE-12.5.4.3 Control Panel Design Features

Panels shall incorporate the following design features.

Panels shall be FM approved and designed to operate on 230 volts AC and 50 hertz. In the event of AC power failure the AC source shall be automatically switch over to the stand-by power source. Upon reinstallation of the AC power, the stand-by power shall be automatically switched over to the AC power.

TE-12.5.4.4 Backup Battery

Each supervisory control panel shall be provided with a backup battery, battery meter, and test switch arranged in accordance with NFPA 72. The backup battery shall be sealed nickel cadmium battery. Batteries for panels which automatically release fire suppression systems shall be capable of operating all systems under maximum normal load and sounding all fire alarm devices for a minimum of 1 hours. Batteries for panels which perform only supervisory and alarm functions shall be sized for 24 hours.

TE-12.5.4.5 Lamps

Indicating lamps shall be furnished on the supervisory control panels for individual alarms and shall be panel face mounted for external access. Indicators shall be incandescent type lamps located on the panel face. Fire alarm indication shall be red, and trouble and supervisory alarm indication shall be amber. System normal indicators shall be green.

TE-12.5.4.6 Alarm and Test Devices

Strobe and horn shall be NEMA 12 rated. Strobe and horn shall be located at supervisory control panel. A horn shall be sounded when any system actuated, The control panel clearly

indicate the place where a fire has broken out by illuminating the zone indicator and sounding the main alarm bell in the panel. The minimum sound output for each alarm bell and horn shall be 85 dB at 3 meters (10 feet) from the device. Then all the local horn shall sound altogether.

An acknowledge push button shall be provided on the panel to silence audible annunciation of fire and trouble alarms. The circuit for this switch shall permit audible annunciation of additional incoming alarms.

Lamp test and reset push buttons shall be provided.

TE-12.5.5 Remote Annunciation Requirements

Upon receipt of any fire protection or smoke detection system fire or trouble alarm, the supervisory control panel shall communicate the specific alarm condition to the operation system of the power station which is supplied by the Contractor.

End of Chapter

**TE-15 INSTALLATION AND TEST OF GENERATOR,
TRANSFORMER AND ELECTRICAL EQUIPMENT**

EQUIPMENT WORKS**ELECTRICAL EQUIPMENT – TECHNICAL SPECIFICATIONS****TE-15 INSTALLATION AND TEST OF GENERATOR, TRANSFORMERS AND
ELECTRICAL EQUIPMENT****TABLE OF CONTENTS**

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TE-15 INSTALLATION AND TEST OF GENERATOR, TRANSFORMERS AND ELECTRICAL EQUIPMENT

TE-15.1 GENERAL REQUIREMENTS

TE-15.1.1 Description of Work

The equipment to be installed and tested under this Contract includes, for generators and all associated equipment; MV power cables, generator and station service transformer, MV switchgear; control, automation and relay boards; LV switchgear; ac and dc auxiliary supplies switchboards, batteries, cable trays, conduit all insulated cables except as described herein.

In general, the equipment furnished by the Contractor will have been shop tested to determine that all parts function properly; and will have been disassembled, if and as required, for shipment.

In the installation of the equipment, only mechanics skilled in their various trades shall be employed. The Contractor shall make all changes and corrections as may be necessary for proper operation to comply with these Technical Specifications.

TE-15.1.2 Installation Drawings and Instructions

The Contractor shall furnish promptly to the Engineer for approval, for the power station, complete erection drawings including bills of material and installation instructions for assembly of the equipment as specified in the General Conditions.

In addition, the instructions shall consist of procedure for assembly and installation the generator and accessories without powerhouse crane.

TE-15.1.3 Delivery to Project Site and Storage of Equipment

In accordance with the General Conditions, the Contractor shall be responsible for delivery and receipt of the equipment at a Thai port or domestic factory, and shall transport it safely, unload and store the cubicle and all other equipment at Site.

Upon completion of the Works, the Contractor shall transfer spare parts to permanent storage as required or directed by the Engineer.

TE-15.1.4 Erection and Testing Schedules

The Contractor shall submit to the Engineer for approval in accordance with the General Conditions, a well coordinated erection and testing. Detailed Works Program showing the order and periods of time in which the Contractor proposes to perform erection and testing of the major items of equipment, for the power station, in order to meet Completion Date.

TE-15.1.5 Use of Crane (not applicable)

The powerhouse crane when installed, tested and accepted by the Engineer, including lifting beam, may be used by the Contractor for installation of the generators as specified herein.

TE-15.1.6 Erection and Testing Personnel

The Contractor shall provide qualified erection and testing engineers to direct and supervise the erection and testing of the equipment, in accordance with these Technical Specifications. The Contractor's erection and testing engineers shall also train EGAT operating personnel; they must be reliable, specialized, competent and experienced.

The Contractor shall, at his own charge and expense, hire all personnel and labor required for the performance of the Works in accordance with the provisions of these Technical Specifications. The Contractor shall, for this purpose, submit to the Engineer for approval, an organization chart. A daily manpower report showing break-down for the various features of the Works shall also be submitted for record purposes.

TE-15.1.7 Test Equipment, Procedures and Logs

All testing meters, instruments and equipment used for field testing shall be furnished by the Contractor .

A written log of test results, for the power station, shall be kept and signed by representatives of the Contractor and the Engineer witnessing the tests. Three (3) copies of certified test reports together with the log of test result shall be submitted to the Engineer.

TE-15.1.8 Inspection and Tests at Project Site

All work performed under this Section shall be subject to inspection by the Engineer. The Engineer shall be permitted to inspect, at all times, all working and storage areas at the Project Site and he shall be invited by the Contractor in charge of EGAT to witness all checking and testing of equipment. The making of any inspection or witnessing of any test shall in no way relieve the Contractor of his responsibility for meeting all of the requirements of this Contract.

The Contractor shall provide promptly, without additional charge, all reasonable facilities, labour and materials necessary for the safe and convenient inspection and test of equipment as specified herein.

TE-15.2 GENERATORS

The Contractor shall assemble, install, test and commission ready for operation the generators and appurtenances, and all equipment associated therewith, as described herein, in the relevant paragraphs of TE-2 of these Technical Specifications, or as directed by the Engineer.

The Contractor shall completely assemble and install generators complete with regulated system, bearings, heaters with thermostats and all appurtenant apparatus attached within or upon the generator frame or housing in accordance with these Technical Specifications, as shown on the drawings or as directed by the Engineer. The generator and appurtenances will be furnished complete with all foundation bolts, soleplates, and dowels for supporting and anchoring to the powerhouse foundation, all specified piping, wiring and all connecting bolts and nuts. Speed signal generator, and overspeed switches shall be installed as specified. Adequate provision shall be made by the Contractor to protect all equipment during assembly from dust, weather.

All equipment shall be set level and in true alignment prior to final bolting in place. Tolerances shall be as established in the manufacturer's instructions or elsewhere in these Technical Specifications. No equipment shall be bolted down permanently until the alignment has been checked and approved by the Engineer.

Grouting of the soleplates will be done at the time of erection procedure specified by the Contractor. Grouting shall be done with non-shrink grout.

The Contractor shall install and connect all electrical wiring and conduits required for the generators. Included in the equipment furnished with the generator will be all terminal boxes complete with terminal blocks and mounting hardware. The Contractor shall install the terminal box equipment and make all necessary electrical wiring connections to the terminal blocks for each generator.

The Contractor shall install all mercury vapor thermometer bulbs, resistance temperature detectors.

The Contractor shall complete the coupling of the generator shaft to the turbine shaft and align the complete shaft and bearings as described in TE-2 of these Technical Specifications.

The Contractor shall mechanically balance the rotor to obtain satisfactory operation of the generators and turbines. (if required)

The Contractor shall install, check all wiring and interconnections, and perform all operational tests for control, indication and alarm. Protection and operation settings of all modules, devices and relays shall be made and recorded.

Following completion of the installation, the Contractor shall make Preliminary Tests which shall include all such tests described in TE-2 of these Technical Specifications and all preliminary checkout and running-in tests. The Contractor shall perform insulation resistance tests and measure the generators field and armature winding resistance's. Measurement of winding insulation resistance shall be made with a 1000 volt Megger tester after the installation but before any external connections are made. The insulation resistance shall not be less than the requirements of IEC or IEEE standards. Following this test the winding shall be dried out by the short circuit method or as approved by the Engineer.

A dielectric test of the stator and field winding of each generator shall be made by applied an ac voltage according to IEC standards continuously for a period of one minute.

The generators shall be given running-in tests and the electrical tests described herein above and in TE-2 of these Technical Specifications in order to determine whether the requirements of these Technical Specifications have been fulfilled. All tests on the generator shall be in accordance with IEC 60034-2. The running-in tests for the generator auxiliary equipment shall be performed concurrently with that of the turbines and governors.

Running-in tests shall include start-up and shutdown sequences, and no- load and on-load operation of the unit for checking bearing and winding temperatures, shaft runout, balance, vibrationless operation and behavior during load rejection.

After the equipment has been erected, serviced and tested, all exposed unfinished surfaces shall be cleaned and painted as described in TG-14. All damaged shop coats shall be repaired before painting. To reduce dusting, concrete in stator area shall be treated by the Contractor by water-glass or similar material and painted.

TE-15.3 MEDIUM VOLTAGE POWER CABLES

The Contractor shall install and test, in the power station, the MV power cables specified in Section TE-3 complete with terminations, frames and covers for the holes in concrete slabs and walls through the cables pass, cable supports and any other connections to complete the cables assembly between the 22 kV panel board, the transformers and 22 kV line as shown on the drawings and as specified in these Technical specifications, and as directed by the Engineer.

The Contractor shall install the MV power cables on cable ducts or trays in the powerhouse.

For the tests after installation, the IEC standards shall be applied. Each cable prior to connection to terminals of any equipment shall be tested by the application of a high ac potential. Contractor shall perform the test in accordance with IEC No 60502. The test voltage shall be maintained for five minutes according to the provisions of IEC standards.

TE-15.4 TRANSFORMERS

The Contractor shall install, connect, test and put into operation the main power transformers and Station service Transformer.

The power transformers may be delivered with its tank filled with oil according to the Contractor's normal practice.

The transformers shall be shipped in accordance with manufacturer's normal practice. Any hose extensions and hose connections required for filling the transformers with oil shall be provided by the Contractor.

The oil shall be furnished by the Contractor as described in TE-4 of these Technical Specifications.

Control cabinet installations and all conduit and control wiring connections shall be made so that each power transformer will be ready in all respects for the connection of the MV and LV winding leads. Terminal and grounding cable connectors shall be furnished by the Contractor,

Transformer oil shall be sampled and tested for dielectric strength in accordance with the latest applicable provisions of ASTM-D 117 "Standard Method of testing Electrical Insulating Oils".

Measurement of insulation resistance of each winding shall be done before energizing of each transformer, with a 1000 volt Megger. The Contractor shall perform tests as outlined by the latest IEEE C57.12.00 including polarity and phase relation tests on the rated voltage connection, and measurement of excitation current at rated voltage on the rated voltage connection.

TE-15.5 CONTROL RELAY AND AUTOMATION PANELS

The Contractor shall assemble, install, test and connect ready for operation the control and relay panels in the powerhouse control room, and the necessary equipment for the remote control described herein, in accordance with the requirements of TE-5 of these Technical Specifications or as directed by the Engineer. Commissioning and putting into operation of all this equipment shall be done by the Contractor on the basis of an approved step-by-step detailed procedure and in the presence of the Engineer.

The Contractor shall install all relays, meters and other equipment if removed from the boards prior to shipment for protection from the hazards of shipping. The Contractor shall then complete all internal and external wiring connections according to the wiring diagrams approved by the Engineer.

The Contractor shall conduct circuit checks and tests of all current, potential and control circuits as required to demonstrate approved by the Engineer that all relays, meters, control switches and other devices are correctly interconnected.

All interconnection wiring for control, protection, indication and alarm functions shall be carefully checked, in particular for each turbine, generator, MV panel board, main power transformer, spherical valves and associated circuit breakers and switchgear .

When all interconnections have been completed and checked, all equipment furnished under this Contract shall be made ready for service. Blocking shall be removed from all relays, meters and other devices, and relay settings made for correct coordination and operation. All input and output circuits and all other control, protection, alarm and indication circuits will be properly checked out. Fault and abnormal system conditions shall be accurately simulated by suitable test equipment and all relays shall be tested and adjusted approved by the Engineer. No operation of any equipment directly associated with the generation or transmission of power shall be attempted prior to complete testing of the control, protection and alarm equipment, as directed or approved by the Engineer. The Contractor shall prepare step-by-step procedures for the purpose of checking and testing of all control, protection, indication and annunciation functions. During these tests, the limit switches and other control devices normally operated by driving machinery shall be operated manually to simulate normal operation through all the specified sequences of operation.

The Contractor shall make any internal wiring changes in the boards required to complete the installation of the equipment or to make the equipment function correctly as approved by the

Engineer. All such changes shall be recorded, and as-built drawings shall be furnished by the Contractor upon completion. No extra payment shall be requested by the Contractor for any and all such work.

All meters and instruments shall be checked by the Contractor. All control, relay, indication and annunciation functions shall be checked for correct operation under all load conditions, and all modes of operation.

TE-15.6 TELESIGNALIZATION -TELECONTROL EQUIPMENT (not applicable)

TE-15.7 MV SWITCHGEAR AND AC AND DC AUXILIARY SUPPLY SYSTEM

The MV switchgear and ac and dc auxiliary supply systems to be installed in the powerhouse, shall comprise the equipment described in TE-7, TE-8, TE-9 and TE-9A of these Technical Specifications.

The Contractor shall assemble, install and connect ready for operation each equipment in the location shown on the drawings. The Contractor shall connect all wires and cables and shall make any internal switchboard wiring or external wiring changes required to complete the installation or to make the equipment function correctly.

The Contractor shall assemble, plumb, level and fasten the battery rack to its foundation at the location shown on the Drawings or as directed by the Engineer. The Contractor shall then install and connect each cell on the racks. If the battery installation is delayed beyond the normal safe storage period recommended by the manufacturer, the Contractor shall make provisions for and bear all costs of putting the batteries on temporary charge at the storage area.

Upon completion of the installation, the Contractor shall check circuit breaker trip calibration and setting for coordination of time characteristics for all circuit breaker trip devices which are in series. All calibration and trip settings shall be checked by artificial loading prior to energization and each thermal overload shall be checked for correct size. Load tests shall be made on each battery as directed by the Engineer. The Contractor shall test each battery charger controls for correct operation.

Functional tests shall be performed with all the load terminals connected. Temporary indicating lights shall be connected to load terminals to be simulated. The temporary indicating lights shall be observed to ascertain if power is being transmitted to the "load". Operational tests shall be conducted with all connections made. Adjustments, repairs and replacements of complete units, sub-assemblies or component parts shall be made as required during the course of the tests.

The circuits, machinery and equipment controlled by these auxiliary switchboards will be operated a sufficient number of times to prove to the satisfaction of the Engineer that all items have been properly installed and will operate properly.

All electrical equipment and materials furnished by the Contractor for MV installation shall have passed adequate routine factory tests in accordance with the applicable IEC Standards. Certified copies of all design tests shall be submitted to the Engineer.

TE-15.8 INSULATED CABLES, CABLE TRAYS AND SUPPORTS AND CONDUITS SYSTEMS

Insulated cables, cable trays and supports and conduits systems shall be furnished, installed and connected by the Contractor ready for operation for all interconnections, except as stated hereunder, and elsewhere in these Technical Specifications, shown on the drawings or as directed by the Engineer. The scope of supply and installation of conduits, cable tray and cable support systems shall be as described in TE-10 and TE-11 of these Technical Specifications.

Insulated cables shall be handled carefully so as to avoid kinking and damage to insulation and jackets. To the maximum extent possible, cable runs shall be continuous from terminal to terminal. No splicing concealed in conduit will be allowed. Cable splices shall comply with the manufacturer's instructions. Cables shall not be bent around a radius less than standard recommended radius.

The Contractor shall furnish and install all necessary lugs and terminals required for a complete installation. Permanent cable identification tags shall be installed on both ends of cables. Tags shall also be provided for splices made in manholes, handholes and boxes. All single and multi-conductor cables will be color or number coded in accordance with TG General Technical Specifications.

Exposed cables shall be installed in a neat and workmanlike manner. For cable tray systems, cables leaving the trays shall be supported clear of the edge of the tray or any structural framework. For cables installed on racks, individual insulating saddles or other suitable means shall be used as supports for each cable.

Where exposed cables are run other than on trays and racks, they shall be run in steel or PVC conduits either horizontally or vertically, avoiding diagonal runs as far as practicable. Horizontal runs shall be supported at frequent intervals; the maximum spacing of supports for the conduits being not over 3 meters. Adequate supports shall be provided at bends, with supports intermediate of the bend where required.

Cable wedges, terminal points, grips or approved equal, and clamps shall be supplied and installed to support vertical or inclined cable runs. Solderless copper terminal lugs shall be inserted and attached with the aid of special crimping tools.

All conductors shall be terminated in accordance with the manufacturer's recommendations and as approved by the Engineer. Stress cones shall be provided where specified or required. The insulation shall be properly tapered with the aid of special tapering tools and the terminal taped and adequately covered, except at potheads.

Each conductor for control wiring shall be terminated in a neat manner at terminal blocks make: Phonix type: UK4 or equivalent.

All medium voltage cable ends shall be kept sealed, and ends cut during installation shall be immediately resealed. This requirement shall include the ends of cables whose have been installed and are awaiting connection as well as cable on reels in storage.

Medium voltage cables shall be terminated in accordance with the manufacturer's recommendations and as approved by the Engineer. Stress cones shall be provided where specified or required. Splices and potheads shall be used where required subject to Engineer's approval. The installation of medium voltage cables shall be done in cable trenches, on cable trays, and supported on walls with proper supports subject to Engineer's approval.

To verify the adequacy of insulation, tests for insulation resistance shall be made after installation for all insulated power cables. Each circuit shall be tested for insulation between conductors, and between conductors and ground, and the minimum insulation resistance shall be as follows:

- a. 600/1000 volt circuits: 1 M ohms.
- b. 600/1000 volt, 3.6/6kV and 18/30kV circuits of cross-sectional area 4 square millimeters or larger insulation resistance as specified in the IEC Publication No 60502, based upon the allowable current carrying capacity of the conductors. Field tests shall be made in accordance with the the applicable IEC Standards.

Each 18/30 kV cable following installation and prior to connection to terminals of any equipment shall be tested by the application of a high ac potential. The Engineer will be informed and invited to be present for test. The Contractor shall perform the tests in accordance with IEC Publication No 60502 or equivalent. The test voltage shall be maintained for 5 minutes and shall be 80 percent of the factory test voltage.

All power and control wiring shall be tested after completion for conformance with the drawings and these Technical Specifications. For the major items of equipment the wiring of control circuits and the control equipment shall be tested with normal voltage applied to the control circuits, and power cabling.

Fire barriers and fire-intruder detection system shall be installed by the Contractor according to Manufacturer's instructions and at the locations approved by the Engineer.

Ducts shall be clean and dry before pulling cables. Pulling tension shall be in accordance with the cable manufacturer instructions for each type of cable and the procedure of pulling. Cable pulling compound shall be talk or a pulling compound approved by the Engineer.

TE-15.9 LIGHTING, GROUNDING, LIGHTING PROTECTION AND FIRE ALARM

Installation details and test for lighting, grounding, lightning protection and fire alarm for all equipment of power plant is specified and described in the respective TE-12 these technical specifications.