Department of Alternative
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THONG NOI DIVERSION WEIR HYDROPOWER PROJECT

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CONTRACT C2

ELECTRO-MECHANICAL EQUIPMENT

VOLUME 2

TECHNICAL SPECIFICATIONS

THONG NOI DIVERSION WEIR HYDROPOWER PROJECT

CONTRACT C2

SUPPLY AND INSTALLATION OF ELECTRO-MECHANICAL POWER PLANT EQUIPMENT

VOLUME 2 : TECHNICAL SPECIFICATIONS

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VOLUME 2 : TECHNICAL SPECIFICATIONS

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SECTION 1

GENERAL

SECTION 1 - GENERAL

S1.01 GENERAL

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.

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

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. The Contractor shall make available to the Owner's Engineer details of the quality control program at the Contractor's and sub-Contractors plants which are applicable to the work before manufacturing begins.

4. Material and equipment not covered by these Specifications shall be subject to acceptance by the Owner's Engineer.

S1.02 SERVICE CONDITIONS

All equipment shall be designed and manufactured for its particular location for continuous operation at the extremes of climate. Specifically, all equipment to be installed indoors shall be designed and manufactured for satisfactory continuous operation at an ambient temperature of 40^{o}C and all equipment to be installed outside shall be designed and manufactured for satisfactory continuous operation at an ambient temperature of 45^{o}C Equipment supplied between ceilings and roofs shall be designed for satisfactory operation at an ambient temperature of 60^{o}C.

S1.03 STANDARDS AND CODES

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.

AFBMA	Anti-Friction Bearing Manufacturers Association
AGMA	American Gear Manufacturers Association
AISI	American Iron and Steel Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWS	American Welding Society
CMAA	Crane Manufacturers Association of America
EN	European Standard
FM	Factory Mutual Engineering Corporation
IEC	International Electro Technical Commission
IEEE	Institute of Electrical and Electronics Engineers, Inc.
ICEA	Insulated Cable Engineers Association
ISO	International Organization for Standardization
NEMA	National Electrical Manufacturers Association

NFPA	National Fire Protection Association
SSPC	Steel Structures Painting Council
UL	Underwriters' Laboratories Inc.
USBR	United States Bureau of Reclamation
PEA	Provincial Electricity Authority

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 shall submit to the Owner’s 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 English language. The Engineer's decision in the matter of equality will be final.

S1.04 UNITS OF MEASUREMENT

Units of measurement shall be in the international system of units (SI).

S1.05 CONTROL AND AUXILIARY POWER SUPPLIES

The following power supplies shall 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 (For control and indication lamps)	125 V (nominal) 108.5 V to 140 V (range)
b)	Lighting and low-power requirements	220 V, single-phase, 50 Hz ac supply (nominal)
c)	Power supply for motor drives and large power requirements	380 V, three-phase, 50 Hz ac supply (nominal)

S1.06 MATERIALS

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 Owner’s Engineer. The materials shall be of good quality and as usually used for equipment of the same kind.

2. 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 com position shall be submitted to the Owner’s Engineer for approval)

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

Mass of Castings of Tension Tests	**Number of Bend Tests**	**Number**
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 Owner's 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. No steel casting shall be finally heat treated before inspection without the permission of the Owner's 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.

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 Owner's Engineer, and reviewed, before repairs are made. Repaired areas shall be re-inspected with MT or PT.

(b) Forgings

Shaft forgings and all other forgings shall be in accordance with ASTM A668, Class D or EN10083-2 Grade C30E or better. Alloy forgings shall have physical properties at least equal to those required by ASTM A668 Class H.

All forgings shall be given such uniform heat treatments as are required to produce. Test coupons shall be provided in accordance with ASTM A370, unless otherwise specified.

(c) Steel Plate for Pressure Vessels

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 0ºC, 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 Owner's 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 Owner's 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 B23, Alloy No. 7.

(h) 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 screws, bolts, studs and nuts for turbine parts shall be in accordance with ASTM A193.

S1.07 ALLOWABLE STRESSES

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.

2. For the rotating parts of 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 according to good practice for parts subject to severe loading conditions and/or shall be further reduced on components where elastic stability governs and combined stresses exist.

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

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.

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

5. Non-specified material shall have a maximum stress of one quarter the minimum specified ultimate tensile strength as given for the appropriate material specification.

S1.08 GENERAL EQUIPMENT REQUIREMENTS

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.

2. 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”.

Surface	**μm**
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

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

S1.09 ELECTRICAL EQUIPMENT

1. The Contractor shall supply all single-line diagrams, three-line diagrams, block diagrams, logic diagrams, schematic control diagrams, cable and wiring diagrams, material take-off, equipment arrangement, detail drawings, and any other documents as deemed necessary to complete the works.

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

3. 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.

4. All joints 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 ANSI/NEMA MG I, 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 250 W shall be 220 V, single-phase. All motors above 370 W shall be 380 V, three-phase. All motors shall be provided with local start – stop push – button switch. 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).

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

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.

(b) Magnetic Contactors and Motor Starters

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

- molded case circuit breaker disconnects with thermal time delay and instantaneous trips
- 380 to 220 V individual fused control transformer
- 220 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 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 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.

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

- 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.

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.

Mechanical targets (operated at 125 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.

(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 of 18 kA for ac and 10 kA for dc circuits, unless otherwise specified.

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 incandescent type for long life and service under conditions of shock, vibration and rough handling unless otherwise specified.

(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.

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.

The instruments shall be damped to ensure that the pointers come to rest rapidly after being deflected from their previous positions.

(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 and as approved by the Owner's 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 Owner's Engineer.

(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.

(l) 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 IP44 for MV and IP33 for LV.

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.

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.

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

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.

Panel lighting and a convenience outlet shall be fitted in all enclosures.

(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:

Purpose	**Wire Size**
Instrumentation	1.0 mm^2
Control	1.5 mm^2
Potential	4.0 mm^2
Current	6.0 mm^2
Power	Determined by rating of protection device, minimum wire size shall be 2.5 mm^2

Internal wiring of solid-state equipment may use solid conductors having a minimum size of 0.5 mm^2.

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.

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

- 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 of 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 super grip 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.

(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.

Terminal material shall be copper, copper alloy, stainless steel or zinc plated and passivated steel. Terminals of devices shall be suitable for 2200 V ac test.

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.

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.

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

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

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

- temperature range 0ºC to 50ºC
- relative humidity 95% at 38ºC, 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 for one (1) minute
- electronic equipment 500 V ac for 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.

(p) Conduits

The conduit shall be rigid galvanized steel conforming to IEC Publication 60423 except where flexible conduit is specified. The flexible conduit shall be galvanized steel and shall have an oil-resistant jacket, and shall conform to the requirements of IEC Publication 60423. Conduit fittings, covers and accessories shall be malleable iron and shall conform to the IEC Publication 60423. The minimum size conduit shall not be smaller than 3/4 in. (20 mm.) except when authorized by the Owner's Engineer.

All conduit runs exposed to moisture or in areas where moisture may be prevalent, such as turbine pit, sump and valve pits, etc, shall be sealed against the ingress of moisture.

(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.

(r) Equipment Grounding

All equipment enclosures containing control or power devices up to 240 V shall have an external ground connector suitable for 35 mm^2 stranded copper ground cable. Hinge door or swing panel shall also be grounded by flexible wiring.

All equipment enclosures containing multiple control units or power devices 380 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/mm^2 under the specified earth fault conditions, however, its cross-section area shall not less than 50 mm^2

S1.10 PIPING

1. 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.

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

3. 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.

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

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

S1.11 WELDING

1. Wherever welding is specified or permitted, the electric arc welding process, using coated welding rods, shall be used. All procedures except for pressure vessels shall be as established under the accepted welding rules of AWS. All procedures for pressure vessels or pressure containing parts shall be to accepted welding rules of ASME Sections VIII and IX.

2. All equipment and personnel shall be qualified in accordance with the AWS and ASME standards.

3. Fillet welds shall not be smaller than 6 mm.; fillet welds larger than 8 mm. shall be made with two or more passes.

4. Stainless type weld, used in the water passages for protection against pitting, shall be of chromium nickel steel. Type, chemical composition and ASTM class of welding rods used for this purpose shall meet with the approval of the Owner's Engineer.

5. Welding electrodes shall be supplied by the Contractor and conform to the AWS Filler Metal Specification A5 or ASME Boiler and Pressure Vessel Code, Section II, Part C. Suitable meters shall be provided to show at all times, the welding current and arc voltage.

6. All welding and welding qualification procedures, including those for field welds, shall be subject to the approval of the Owner's Engineer.

7. The Contractor shall furnish proof that welding operator and welders having the requisite qualifications are being employed. The Contractor shall furnish the necessary copies of all test reports, together with copies of the supplier's test reports on welding rod.

8. All unacceptable defects in welds shall be chipped out to sound metal. The areas shall be checked by magnetic particle testing (MT), dye penetrant (PT), radiography (RT) or ultrasonic (UT) by the Contractor as directed by the Owner's Engineer, to ensure that the defect has been completely removed before repair welding.

9. Magnetic particle examination (MT) shall be performed in accordance with the ASME Code Section V, Article 7 and ASTM E709. Acceptance shall be in accordance with ASME Code, Section VIII, Appendix 6 and ASTM E125.

10. Dye penetrant examination (PT) shall be performed in accordance with ASME Code Section V, Article 6 and ASTM e165. Acceptance shall be in accordance with ASME Code, Section VIII, Appendix 8 and ASTM E433.

11. Radiographic examination (RT) on welds for pressure containing parts shall be performed in accordance with paragraph UW-51 of ASME Code, Section VIII, RT of welds on structural steel where required, including standard of acceptability, shall be performed in accordance with AWS D1.1, Structural Welding Code. RT examination and standards of acceptance of ferrous castings up to 50 mm. thick shall be in accordance with ASTM E446 for high-pressure castings, and for ferrous castings 50 to 115 mm. thick, ASTM E186.

12. Ultrasonic examination (UT) shall be performed in accordance with the ASTM Code, Section V, Article 5. Acceptance shall be in accordance with the ASTM Code, Section VIII, Appendix 12 and Section V, Article 5.

S1.12 NAMEPLATE AND MARKING

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.

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).

3. 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	Red
Phase B	Yellow
Phase C	Blue
Neutral	White Grey
Ground	Green
Ground/Earth	Green cap

AC Single phase

Line	Black
Neutral	White Grey

DC

Positive	White
Negative	Black

4. Medium and High Voltage Equipment label

A	Red background White letter
B	Yellow background Black letter
C	Blue background White letter

5. Size of letter shall not be smaller than 20 x 15 cm. (wide x high).

S1.13 PAINTING

1. 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.

2. 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 3.

3. Paints shall be applied only to surfaces, which are free of moisture as determined by sight and touch. The ambient temperature shall be at least 5ºC above the minimum temperature recommended by paint manufacturer for application on any coat.

4. 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. A sufficient number of measurements shall be made to establish the final thickness.

5. The color schedule, by Munsell color notation, for the equipment shall match the existing equipment, structures, vessels, etc.

6. The painting systems referred to in these specifications shall be as follows:

Paint System 1 - Surfaces in Contact with Water

(a) General

All surfaces shall be painted with an inorganic zinc primer and two coats of liquid epoxy. Final shop painting shall not be applied within 100 mm. of field welding. These areas will only receive one coat of inorganic zinc primer that can be removed prior to welding.

(b) Surface Preparation

Surfaces shall be blast-cleaned in accordance with SSPC-SP10.

(c) Paint Application

(i) Materials

The painting system shall consist of one coat of inorganic zinc primer and two coats of a compatible liquid epoxy. All components shall be from the same manufacturer and the manufacturer's instructions shall be rigidly adhered to.

(ii) Film Thickness

The dry film thickness of the primer shall be 80 µm. The dry film thickness of each of the liquid epoxy coats shall be between 200 µm and 260 µm.

(d) Final Dry Film Thickness

The final thickness of the three coats shall be between 480 µm and 600 µm. This shall be checked by a Type B film thickness gauge, supplied by the Contractor, calibrated on metal identical in composition, thickness and surface preparation and finish to that being painted.

Paint System 2 - Surfaces in Contact with Oil

(a) Surface Preparation

Surfaces shall be blast-cleaned in accordance with SSPC-SP10.

(b) Paint Application

The painting system shall consist of two coats of two-pack epoxy resin zinc phosphate with minimum dry thickness of 25 µm per coat.

(c) Final Dry Film Thickness

A sufficient number of readings with a gauge supplied by the Contractor shall be taken to ensure a minimum film thickness of 50 µm is attained.

Paint System 3 - Electrical Equipment, Cubicles, Panels and Boards

(a) Surface Preparation
Surfaces to be painted shall be blast-cleaned in accordance with SSPC-SP6.

(b) Paint Application

(i) Materials

The painting system shall consist of one coat of two-pack zinc rich epoxy primer and one coat of two-pack high gloss topcoat based on epoxy resin.

(ii) Film Thickness

The dry film thickness of the primer shall be 50 µm. The dry film thickness of the finish shall be 50 µm.

(c) Final Dry Film Thickness

A sufficient number of readings with a gauge supplied by the Contractor shall be taken to ensure that a minimum final film thickness of 100 µm is attained.

Paint System 4 - Mechanical Equipment, Exposed Carbon Steel Piping

(a) Surface Preparation

Surface of pre-engineered, factory painted products such as pumps, motors and integral piping shall be degreased and cleaned in accordance with SSPC-SP1 and SSPC-SP2. Other surfaces to be painted shall be blast-cleaned in accordance with SSPC-SP10.

(b) Paint Application

(i) Materials

Manufacturer's standard paint finish for pre-engineered products such as pumps, motors and integral piping shall be over coated with one coat of compatible two-pack high solid, aliphatic polyurethane topcoat. For other surfaces the painting system shall consist of one coat of inorganic zinc primer, one coat of liquid epoxy and a finish coat of two-pack high solid, aliphatic polyurethane topcoat.

(ii) Film Thickness

The dry film thickness of the primer shall be 50 µm. The dry film thickness of each of the liquid epoxy coats shall be between 200 µm and 260 µm. The dry film thickness of the finish shall be 80 µm.

(c) Final Dry Film Thickness

A sufficient number of readings with a gauge supplied by the Contractor shall be taken to ensure that a minimum film total thickness of 330 µm is attained. Over coating shall also be sufficient to ensure complete hiding of underlying coating.

Paint System 5 - Civil - Miscellaneous Metalwork

(a) Surface Preparation

Surfaces to be painted shall be blast-cleaned as specified by the Owner's Engineer.

(b) Paint Application

(i) Materials

The painting system shall consist of one coat of inorganic zinc primer, one coat of polyamide epoxy and a finish coat of acrylic asphaltic polyurethane. All components shall be from the same manufacturer and the manufacturer's instructions shall be rigidly adhered to.

(ii) Film Thickness

The dry film thickness of the primer shall be 75 µm. The dry film thickness of the intermediate shall be between 100 µm and 150 µm. The dry film thickness of the finish shall be between 40 µm and 50 µm.

(c) Final Dry Film Thickness

The final thickness of the three coats shall be between 215 µm and 275 µm.

S1.14 GALVANIZING

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.

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

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

S1.15 PACKING

1. All the Equipment shall be carefully packed. The same precautions and care shall be taken for equipment (including components) which cannot be packed or crated.

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 S1.14.

S1.16 LUBRICANTS

1. The Contractor shall submit to the Owner's 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.

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.

S1.17 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:

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

The Contractor shall submit to the Owner's Engineer certified copies of all test results. The results of each test shall be recorded in the form of test certificates or test reports.

The acceptance of factory inspection and tests shall not prejudice the right of the Engineer and Owner 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.

If facilities are not available at the manufacturer's factory to execute the tests specified, the Contractor shall submit details of the proposed alternative arrangements.

The Contractor may offer type test results for identical equipment in lieu of the type tests specified, in which case the Owner's 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 Owner's 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 Owner and the Engineer.

The Contractor shall prepare and submit the detailed plan 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 Owner's Engineer.

The Contractor shall also prepare and submit the reports based on the test results. The Contractor, with advice from the Owner's Engineer 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 Owner 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.

(iv) Provisional Acceptance Tests

The Contractor shall submit all testing procedure for Engineer's approval prior to test start.

(d) Mechanical and Electrical Requirements for Inspection and Testing

(i) Pressure Tests

The Contractor shall give adequate notice of any proposed pressure tests. Free access to the testing equipment shall be allowed to the Owner's 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 at a test pressure of 150% of the maximum working pressure. Pressure shall be maintained at test pressure for not less than 30 minutes without additional pressurizing fluid being added.

(ii) Circuit Tests

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

- 380 V power circuits	2200 V ac to ground
- 125 V dc circuits	1500 V ac to ground
- 220 V ac and control circuits	1500 V ac to ground

S1.18 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.

S1.19 MAINTENANCE TOOLS AND INSTRUMENTS

(1) The Contractor shall supply all maintenance tools and instruments required or likely to be required for the proper maintenance of the Plant during its service life.

The maintenance tools and instruments shall be sufficient to enable full dismantling and reassembly of the Plant, testing for wear or distortion of all wearing parts, diagnosing and locating faults in electronic equipment and replacement of all spare parts ordered.

(2) The Contractor may use the mechanical handling equipment for initial erection of the Plant but shall make good any wear or damage before handing over.

(a) Maintenance equipment shall be suitably arranged in metal tool boxes or cabinets each fitted with a padlock. Each tool box or cabinet shall be clearly and permanently marked with the name of the plant to which the maintenance tools and instruments applies and with a list of the equipment it contains.

(b) Large tools may be mounted on a suitable shadow board arranged for wall mounting.

End of Section

SECTION 2

TURBINE

SECTION 2 - TURBINE

S2.01 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.

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 Owner's Engineer.

S2.02 TYPE AND DESCRIPTION

The turbine consists of two (2) sets for main powerhouse and four (4) sets for emergency channel. Turbine shall be Kaplan type with speed increaser to up turbine speed of not less than 125 rpm to generator speed of not less than 750 rpm for main powerhouse and Axial flow type with generator speed of not less than 250 rpm for emergency channel.

S2.03 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:

(a) Water Surface Elevation

Weir		
- Maximum water storage level	+198.80	m MSL
- Normal water storage level	+191.00	m MSL
Tailwater		
- Maximum tailwater level	+187.55	m MSL
- Minimum tailwater level	+186.25	m MSL

(b) Main Powerhouse

- No. of unit	2	units
- Rated net head	3.5	m
- Rated discharge	38.5	m^3/s
- Total turbine output (2x1,190 kW)	2,380	kW
- Total installed capacity (2x1,119 kW)	2,238	kW
- Turbine efficiency (Not less than)	90	%
- Turbine centerline	+183.00	m MSL
- Erection bay level	+201.20	m MSL
- Turbine rated speed	Not less than 125	rpm
- Generator speed	Not less than 750	rpm

(c) Emergency Channel

- No. of unit	4	units
- Rated net head	3.5	m
- Rated discharge	8.0	m^3/s
- Total turbine output (2x244 kW)	976	kW
- Total installed capacity (2x229 kW)	916	kW
- Turbine efficiency (Not less than)	89	%
- Turbine centerline	+183.50	m MSL
- Erection bay level	+201.20	m MSL
- Turbine rated speed	Not less than 250	rpm
- Generator speed	Not less than 250	rpm

S2.04 OVERSPEED, RUNAWAY SPEED, CRITICAL SPEED AND MAXIMUM PRESSURE

The Contractor shall guarantee that the maximum speed rise and maximum runaway speed of the turbine under any conditions shall not be greater than 1.8 and 2.9 times of the rated speed respectively. As well, the maximum hydraulic pressure due to maximum turbine output load rejection at the elevation of the turbine center shall not exceed 1.5 times of rated net head. If not, the Contractor shall state in his proposal clearly how to take the countermeasure to limit the speed rise and pressure rise as above such provision of proper.

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).

S2.05 TURBINE OUTPUT AND EFFICIENCY

The Contractor shall responsible for design, manufacture, install and test the turbine in associated with or without speed increaser to couple generator in capable to deliver the minimum generator kVA output as specified generator chapter.

S2.05.1 TURBINE OUTPUT

The Contractor shall guarantee the output of each turbine under rated net head of 3.50 m and discharge of 38.50 m^3/s shall not be less than 1,190 kW for main powerhouse and rated net head of 3.50 m and discharge of 8.00 m^3/s shall not be less than 244 kW for emergency channel.

If the measured output is below the corresponding guaranteed output value after the site completion test, the Contractor shall be bound to modify the turbine within a period of six (6) months in order to achieve the guaranteed output, If, after modifications have been carried out, the turbine still fails to achieve the guaranteed output, or if it is mutually agreed to waive the

modifications or if the modifications are not possible, a sum equal to the stated in Special Conditions Section in Volume 1 of Contract shall be deducted from Contract Price.

S2.05.2 TURBINE EFFICIENCY

Before commencing manufacturing of the turbine, the efficiency of the turbine shall be determined by 3D CAD models, optimized by CFD and Finite Element Analysis (FEA).

The efficiency of turbine under rated output and rated net head of 3.50 m. shall be proposed and guaranteed by the Contractor. The guaranteed turbine efficiency shall not be less than 90.0 % for main powerhouse and not be less than 89.0 % for emergency channel.

Prototype efficiency shall be stepped-up from the measured mathematical 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).

If the turbine output guarantee cannot archive (from field test), the guarantee efficiency of turbine is expected to fail. On the failure of efficiency, the Contractor shall pay for Owner according to the stated in Special Conditions Section in Volume 1 of Contract and/or mutual agreement between the Owner and Contractor.

The layout arrangement, Hill curve (or) turbine prototype Performance Curve indicating allowable operating Range, turbine prototype efficiency, needle valve opening, output and discharge against net head and the curves which consistent with the guarantees relating to efficiency and output of Kaplan type for main powerhouse **shall be submitted together with the Bid. Failure to submit will reject the Bid Proposal.**

S2.06 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 shall be in accordance with IEC Publication No.60609 (Cavitation Pitting Evaluation in Hydraulic Turbines, Storage Pumps and Pumps-Turbines).

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 new runner supply.

S2.07 QUALITY OF WATER

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

S2.08 RUNNER

The runner blade shall be casting or fabricated construction of stainless steel, according to ASTM A743 Grade CA-6 NM, GX4CrNi13-4. The runner hub shall be spheroidal graphite cast iron or fabricated construction of stainless steel, according to ASTM A536 grade 70-50-05, EN-GJS-500-7, GGG50 or ASTM A743 Grade CA-6 NM, GX4CrNi13-4 respectively. 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 runners shall be made up of special steel along with blade assembly placed on the shaft axially. The curved blades are welded to the shaft and produce only limited axial thrust. The hydraulic shape of the blades shall be designed to obtain the best possible results taking into consideration of cavitation and efficiency. Both ends of the blades shall be fitted in runner discs and welded with intermediate discs of the runner following a specific procedure. Blades of wider runners shall be supported by multiple discs. Runners shall be carefully balanced before final installation of the turbine and shall be subject to crack detection control.

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.

S2.09 TURBINE BEARING (IF APPLICABLE)

The anti-friction and self-aligning spherical roller bearings shall be installed at both runner shaft ends. The bearings shall help in the reduction of frictional force and leakage occurring through the bearing. The bearings shall be long-lasting and require minimal maintenance and shall be able to continuous operating for not less than 100,000 hours. The manufacturer’s bearing shall be well-know. The bearing temperature sensor at each shaft bearing shall be PT 100 type.

S2.10 MAIN SHAFT

S2.10.1 TURBINE SHAFT

The turbine shaft be made of forged, open-hearth, carbon or alloy steel, properly heat treated, or alternatively made of a thin-walled center portion fabricated of carbon steel, connected to end piece of forged steel.

Torque between the runner and the shaft shall be transmitted by means of coupling bolts. The turbine supplier shall furnish all bolts and nuts for attaching the runner to the turbine shaft coupling and to the speed increaser shaft.

S2.10.2 TURBINE-GENERATOR COUPLING

All coupling dimensions shall be as mutually agreed upon by the turbine and speed increaser (if applicable) suppliers and the Engineer. The required device, if necessary for attaching the turbine shaft to the speed increaser shaft (if applicable) shall be furnished by the Contractor.

S2.10.3 BLADE ADJUSTING ROD (IF APPLICABLE)

The operating rod shall serve for positioning of the runner blades and shall be operated in the bore of the low-speed shaft, and shall be connected to the externally mounted runner blade servomotor with the crosshead, situated in the runner hub.

S2.10.4 SHAFT CONNECTION

The end of the turbine shaft shall be finished to dimensions agreed upon with the speed increaser (if applicable) manufacturer. The Contractor shall submit the supplier of speed increaser with the necessary exact dimensions for drilling the speed increaser shaft.

S2.10.5 SHAFT ALIGNMENT

The Contractor shall be responsible for aligning the combined turbine, speed increaser (if applicable) and generator shaft. The turbine supplier shall first check the alignment of the shaft individually and the determine the relative positions of the coupling halves for best overall alignment, then couple them together and accurately align the entire shaft assembly.

S2.11 CASING

The casing shall be provided with turbine casing, corner casing and base plate frame. They shall be made of cast or fabricated steel plates welded and shall be designed to withstand a hydraulic pressure test equivalent to 150% of the maximum pressure occurring under load rejection conditions. The turbine casing and corner casing shall be integrated and installed to the base plate frame by bolting. The corner casing shall be equipped with the suction valve.

The bearing housing shall be designed to prevent water leakage into bearings and contact of lubricants with working water.

Wetted surfaces of the draft tube shall be painted to System 1, S1.13 Painting and non-wetted exposed surfaces to System 4, S1.13 Painting.

S2.12 EXTERNAL FLYWHEEL (IF APPLICABLE)

If applicable, external flywheel shall be provided in order to control both maximum overspeed of the machine and maximum hydraulic pressure in open channel within the specified guarantee values. The proposal of surge tank shall not be accepted. The solution selected by the Contractor shall be submitted 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 and included in Price Schedule.

S2.13 GUIDE VANE AND LEVER ARM OR OPERATED VALVE

S2.13.1 GUIDE VANE AND LEVER ARM
(FOR TURBINE WITH ADJUSTABLE GUIDE VANE ONLY)

Guide vane shall be provided in turbine casing. This guide vane with stem shall be spheroidal graphite cast iron or fabricated construction of stainless steel, according to ASTM A536 grade 70-50-05, EN-GJS-500-7, GGG50 or ASTM A743 Grade CA-6 NM, GX4CrNi13-4 respectively. The proposed other material standard shall not be accepted. The guide vane shall be uniform in shape and their cross-sections shall be such as to direct properly and accelerate gradually the water entering the runner smoothly with a minimum of friction and hydraulic disturbance.

The guide vane is set precisely in the turbine casing and they can serve as the closing device of the turbine if there is a lower head. It shall be fitted independently to control the amount of water that is to be passed on the runner shaft assembly.

Guide vane shall be placed in highly resistant slide bearings, which do not require any maintenance. The water flows over and under the inlet guide vane which directs flow to ensure that the water hits the runner at the correct angle for maximum efficiency. The water then flows over the upper runner blades, producing a torque on the runner, then through the center of the runner and back across the low runner blades producing more torque on the runner. The guide vane shall be automatically controlled using lever arms and servomotors.

The operating mechanism shall consist of hydraulic servomotor, lever arm and counterweight at lever arms end, arranged to operate the valve properly. The valve shall be held open by hydraulic pressure in the cylinder only and close by counterweight. Hydraulic servomotor having a capacity sufficient to supply the maximum force necessary to operate the guide vane under maximum operating head, at the minimum oil pressure shall be provided. The servomotor shall be capable of moving the guide vane from a complete close position to a fully open position in one stroke and vice versa. The gate opening and closing shall be 10-15 s equally. 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 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.

S2.13.2 OPERATED VLAVE
(FOR TURBINE WITH FIXED GUIDE VANE OR WITHOUT GUIDE VANE ONLY)

The operated valve shall be gate type with motor operated or hydraulic operated. The size shall be designed by manufacturer. 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 valve shall be a standard, manufactured type to ensure interchangeability of parts.

S2.14 DRAFT TUBE

The rectangular draft tube shall be integrated into base plate frame. It shall be made of welded plate steel and shall be adequately ribbed and stiffened to prevent distortion. Prior to shipment, it shall be completely assembled and match-marked in the shop with all ribs accurately fitted.

Wetted surfaces of the draft tube shall be painted to System 1, S1.13 Painting and non-wetted exposed surfaces to System 4, S1.13 Painting.

S2.15 WRENCH AND TOOL

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

The Contractor shall submit in “Schedule 6” a detailed description and itemized list of the maintenance tools and instrument whose he proposes to furnish.

S2.16 SHOP ASSEMBLY AND TEST

S2.16.1 SHOP ASSEMBLY

All turbine components such as casings, runner, guide vane, regulating arm, draft tube, etc. shall be assembled or sub-assembled at the Contractor's shop to prove the design, construction and machining for proper fits and clearances.

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 Owner’s Engineer for review prior to the first shop assembly inspection.

S2.16.2 HYDRAULIC STATIC TEST

The casings and hydraulic servomotor cylinders shall be hydrostatically tested with one and a half (1.5) times of maximum design pressure for ten (10) minutes at least.

S2.16.3 SHOP TEST WITNESS

The shop assembly tests for turbine set and other associate parts shall be witnessed by Owner’s Engineer. All costs for shop assembly with at least two (2) Owner’s representatives shall be responsible by the Contractor.

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

S2.17 FIELD TEST

S2.17.1 GENERAL

The field tests after turbine installation shall be done to determine whether the equipment meets these technical specifications and "Guaranteed Characteristics" of Contract.

S2.17.2 COMMISSIONING AND ACCETPANCE TEST

Commissioning and acceptance tests shall include**.**

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 Owner's Engineer. 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 the guaranteed output is met.

The output test shall be carried out at net heads as close as possible to the net head for which turbine power is guaranteed in the Technical Schedules. 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 measured 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 output test. This test shall be carried and for 8 hours.

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.

Owner's Engineer 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 Owner's Engineer two copies of the records and tabulated results of the index tests, certified by the testing 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 generator losses, and the guaranteed efficiencies of the speed increaser (if applicable).

The power output of the generator shall be measured with the use of calibrated electrical test instruments. Unless otherwise mutually agreed upon by the Contractor and Owner's Engineer, the tests shall be conducted in accordance with IEC Publication 62006 "Hydraulic Machines - Acceptance Tests of Small Hydroelectric Installations".

S2.18 SPECIFIED SPARE PARTS

The Contractor shall supply the following specified spare parts of each turbine type.

a)	Turbine bearing metal	One (1) complete set
b)	Bearing temperature sensor (PT 100)	Two (2) sets
c)	Guide vane (if applicable)	One (1) set
d)	Bush for Guide vane (if applicable)	One (1) complete set
e)	Sensor for guide vane position (if applicable)	Two (2) sets
f)	Seal, packing, piston rings, etc. for guide vane servomotor (if applicable)	One (1) complete set
g)	Packing and seal	One (1) complete set

End of Chapter

SECTION 3

GOVERNOR

SECTION 3 - GOVERNOR

S3.01 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.

S3.02 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 pressure unit, 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.

The electric/electronic components shall be arranged on plug-in modules enclosed in unit control and governor panel with indicating or digital instruments and controls mounted on the face of the module panels in standard arrangement for hydro power plants. A turbine control panel, which may be combined with the governor panel or adjacent to it, shall be provided for mounting turbine and generator instruments and controls as hereinafter specified.

The system shall be so arranged that manual and automatic control facilities are available both locally in the turbine control panel and remotely through the supervisory control and monitoring system specified under Clause Control, Monitoring and Protection System 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. Means shall be provided so that speed/load adjustment may be made by hand either at the turbine control panel or at the remote-control room or by the automatic synchronizing equipment.

S3.03 CAPACITY AND OPERATING CONDITION

S3.03.1 CAPACITY

The governor oil pressure for turbine with guide vane shall have sufficient capacity when deriving energy from the air tank or nitrogen accumulator only to operate the guide vane servomotor through complete opening and closing stroke at any head up to maximum head when the pressure in tank is at its lowest value. The governor shall have sufficient capacity, without overloading, to hold the adjustments of the guide vanes at all openings.

The governor electrical storage for turbine without guide vane shall have sufficient energy storage to operate the operated valve through complete closing stroke at any head up to maximum head.

S3.03.2 OPERATING CONDITIONS AND REQUIREMENTS

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 as defined in the guaranteed characteristics so that the speed rise and maximum pressure rise shall not exceed the value defined in the guaranteed characteristics.

The governor shall be capable of controlling with stability, the speed of 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

S3.04 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 for turbine with guide vane and operate the operate valve for turbine without guide vane.

d) Power supply supplied from powerhouse is 125 V DC system as specified in Clause S1.05, 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.

h) Start-up circuit of the governor which shall obtain its supply from the station DC supply on the governor common supply and shall start the unit from standstill (only for electronic device) since DC pump is not necessary.

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.

S3.05 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 Owner's Engineer 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.

S3.06 INSTRUMENT AND CONTROL DEVICE

S3.06.1 GENERAL

The Contractor shall furnish and install on the unit control board, all indication and control devices for speed, guide vane position of turbine governor as described in S3.06.2 Governor Panel herein below and as further required to satisfy the remote-control philosophy of the supervisory control and monitoring system described in this Technical Specifications.

S3.06.2 GOVERNOR PANEL

The governor panel, which integrated within the unit control panel specified hereafter, shall be provided as a minimum with the following controls and instruments which are realized as touch panel:

a) Speed indicators (Tachometers)

b) Guide vane position or Operated valve position indicators

c) Local/remote control switches

Selector switches to permit operation of the units under local step by step control, local automatic control and remote automatic control shall be provided to satisfy the control philosophy described under this Technical Specifications.

d) Automatic shutdown

Two (2) switches, one (1) for normal stopping and one (1) for emergency shutdown shall be provided.

e) One (1) upstream and one (1) downstream water level-indicators

S3.06.3 TURBINE CONTROL PANEL

The electronic turbine governor is incorporated in the programmable logic controller of the unit control panel. Therefore, a separate governor panel and turbine control panel shall not be necessary.

In addition to instruments listed in Clause of Turbine of this Technical Specifications, the Contractor shall furnish and mount as a minimum the following instruments and controls on or in the turbine control panel. Reference is also made to Clause of Control, Monitoring and Protection System regarding the unit local control from this panel and all equipment necessary to meet these requirements. All wiring in the panel shall conform to the provisions of S3.05 Wiring.

All the necessary instruments, switches, alarms etc. are listed up in this Technical Specifications.

a) Oil pressure gauge (for turbine with guide vane only)

Pressure gauges graduated in bars to indicate the pressure in the pressure receivers, as required.

b) Oil pressure failure switch (for turbine with guide vane only)

Two (2) pressure switches, suitable for 125 V DC, one (1) switch to initiate alarm on low governor oil pressure and the other to cause shutdown and prevent starting of the unit on extremely low governor oil pressure.

c) Annunciator panel as alarm listing at the unit control panel with minimum twelve (12) windows, complete with alarm.

d) Annunciator alarm bell

e) Three (3) push buttons for annunciator accept, reset and test function.

f) One (1) control function at the unit control panel for control valve of the bearing cooling water system with red and green indicating lights. (for turbine with guide vane only)

g) Emergency shutdown push button, with protective cover, for complete shutdown of the unit and remote tripping of circuit breaker

h) Space for instruments furnished by the generator manufacturer, (alternatively these instruments may be accommodated, together with the temperature instruments specified under Generator of this Technical Specifications, in a separate panel)

i) Thermometers for each generator bearing oil temperature
ii) Thermometer for each generator bearing metal temperature

S3.07 GOVERNOR OIL PRESSURE UNIT (for turbine with adjustable guide vane only)

S3.07.1 GENERAL

The Contractor shall design the governor oil pressure unit having capacity and reliability as required for operation of governor. The preliminary schematic diagram for governor control is shown in drawing no. THN-EM-01 Schematic Diagram of Oil Pressure Unit for Turbine as attached herewith.

The governor oil pressure unit for each unit shall be provided with oil pump with AC motor, control valve, pressure relief valves, safety valve, oil sump tank, nitrogen accumulator, filter, pressure switch, piping, indicators, instrument and protective devices as specified hereinafter.

The governor oil pressure unit for turbine with fix guide vane or without guide vane (if applicable) shall be a proven manufacturer’s standard design having capacity and reliability.

S3.07.2 OIL PUMP

One (1) motor driven oil pump, gear type, having a capacity per minute of not less than 1.5 times the total oil volume of the guide vane servomotors, shall be provided. It shall be possible to run oil pump continuously so that it discharges to the oil sump tank or to nitrogen accumulator without overheating the oil.

The motor shall be suitable for operation on 380 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 each motor shall be provided. An indicator light shall show which pump is lead pump. An alarm shall be provided to indicate continuous running of the lag pump over an adjustable period of time.

The oil pumps shall start unloaded under all conditions. The system shall be provided with adjustable unloader valve, pilot control valve, safety relief valve, check valve, temperature relay and pressure switches, necessary hand-operated hand pump and valves to permit isolating either pump from the oil pressure system and its removal for repairs without losing oil pressure.

An adjustable temperature switch with two electrically separate contacts suitable for operation at 125 V DC located in the pump suction side for high oil temperature alarm.

A suitable oil strainer shall be provided in the suction line of each oil pump.

S3.07.3 NITROGEN ACCUMULATOR

The nitrogen accumulator (nitrogen/oil) shall be of welded construction, designed, constructed and tested in accordance with the ASME Code for "Unfired Pressure Vessels, Section VIII" certified by Lloyd's Register of Shipping or TOV or equal Standard as approved by the Engineer. The accumulator shall be designed for not less than 1.5 times of maximum allowable working pressure and keep at this pressure for 30 minutes. The accumulator shall be sized to open and close the guide vane three times (close-open-close) from minimum oil level without any additional oil from the governor oil pressure unit. A safety valve shall be supplied and set in accordance with ASME Boiler and Pressure Vessel Code, Section VIII.

Pressure system shall be composed of pre-charged nitrogen bottles in parallel and of nitrogen/oil accumulator. The latter shall consist of the pressure vessel, the flexible bladder, the nitrogen insert valves, and the hydraulic connecting unit with check valve and isolating valve.

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

For recharging with nitrogen, the accumulator has to be supplied with the refilling kit (not spare nitrogen bottle).

S3.07.4 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 system. 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, 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 tank shall be painted as set forth to System 2, S1.13 Painting for inside and System 4, S1.13 Painting for outside and steel piping.

The maximum oil temperature shall not exceed 65^{o}C.

S3.07.5 PIPING AND VALVE

The Contractor shall supply all interconnecting piping and valves between oil pumps, oil sump tank and nitrogen accumulator as well as connecting the governor oil pressure unit to 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/oil system.

S3.07.6 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 and approved by Owner's Engineer.

S3.08 WRENCH AND TOOL

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

The Contractor shall submit in "Schedule 6" a detailed description and itemized list of the maintenance tools and instrument whose he proposes to furnish.

S3.09 INSPECTION AND TEST

S3.09.1 GENERAL

All equipment and material shall be subject to inspection and testing as specified in S1.17 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.

Type tests may be offered by the Contractor as specified in S1.17 Inspection and Test-Electrical/Mechanical. The Contractor shall give evidence to Owner's Engineer as to the similarity of the equipment tested and the Contract equipment.

S3.09.2 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 S1.17 Inspection and Test-Electrical/Mechanical.

b) Hydrostatic Tests

Hydrostatic tests shall be as specified in S1.17 Inspection and Test-Electrical/Mechanical.

c) Shop Tests

Shop tests shall be as specified in S1.17 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.

S3.09.3 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 Contractor’s Supervisor 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.

Full load rejection and line rejection tests shall be conducted at the site to investigate the governor control response and to ensure that the unit will not be tripped by overspeed or over-voltage protection equipment.

Other tests on governing equipment are part of S2.26 Field Test.

S3.10 SPECIFIED SPARE PARTS

The Contractor shall supply the following specified spare parts of each turbine type.

a) Speed signal device (SSD)	One (1) complete set
b) Sensing device	Two (2) of each type
c) Limit switch	Two (2) of each type
d) Auxiliary relay and conductor	10 % or at least two (2) of each type
e) Transducer	10 % or at least two (2) of each type

f)	Proportional valve (if applicable)	One (1) complete set
g)	Solenoid valve (if applicable)	One (1) of each type
h)	Oil filter (if applicable)	One (1) set
i)	Accumulator Bladder (if applicable)	One (1) set

End of Section

SECTION 4

SPEED INCREASER

SECTION 4 – SPEED INCREASER

S4.01 GENERAL

This section specifies the detailed requirements for the design, manufacture and testing of speed increaser, with associated equipment, to be furnished.

S4.02 TYPE AND DESCRIPTION

The speed increaser shall be designed as a double helical gearing optimized for this particular application, anti-friction bearings and perfectly-matched oil lubrication.

The unit configuration is a spur gear or helical parallel shaft gear.

The gear drive is a parallel shaft arrangement enclosed in a rigid, heavy walled fabricated steel casing, employing gear wheels rotating on shafts supported by anti-friction bearings.

The low speed shaft shall be 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 shall be done by means of and the flexible coupling.

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

The speed increaser shall be equipped in accordance with the specifications and include the necessary provisions for temperature measurement devices to monitor operating parameters

The minimum guaranteed efficiency of speed increaser shall not be less than 97.5%.

S4.03 DESCRIPTION OF COMPONENTS

S4.03.1 GEAR ACCURACY

The pinion and helical gears shall be precision hobbing, carburizing and precision surface to DIN 3990 Grade 6 or corresponding to an AGMA Quality 11/12.

S4.03.2 HOUSING

The gear 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. 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.

Inspection openings shall be provided and arranged in such a way as to permit internal speed increaser inspection.

S4.03.3 BEARING

The bearings shall be anti-friction type bearings of any renowned manufacturer of such bearings like SKF, NKE, FAG or INA etc. with pressure oil lubricating system.

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 life time shall be at least 100,000 operating hours.

S4.03.4 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 be fitted through the access opening in power box.

S4.03.5 LUBRICATION SYSTEM

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

This system will be mounted on the gear, incorporating a sump tank, driven pumps, filter, air to oil heat exchanger, check valves and sensors. The oil sump tank is incorporated in the gear housing.

If applicable, 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.

S4.03.6 LUBE OIL ROUTING

All components except the oil cooler shall be mounted on gear housing (including oil sump). In operation, oil is drawn from the sump past vertical check valves into the oil pump at low pressure. Upon exiting the pump, the higher pressure oil is fed through oil filter and into the oil cooler.

Upon exiting the heat exchanger, the oil passed through a series of gauges and sensors after which it will be distributed to the key inlet points. Excess oil will be relieved back to sump along with oil whose is exhausted from areas of drive system.

The first oil filling shall be provided by the Contractor.

S4.03.7 INSTRMENT AND OTHER EQUIPMENT

The pressure oil lubrication system shall consist of an oil pumping unit with auxiliaries. 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) mechanical driven pump by high speed shaft
(b) One (1) electric driven pump (if applicable)
(c) One (1) air/oil cooler with closed oil circuit (if applicable)
(d) Two (2) oil filters with electric contamination indicator
(e) One (1) flow control valve with contacts installed in the main pressure line
(f) One (1) pressure switch installed in the main pressure line
(g) One (1) pressure gauge in the oil circuit pipes
(h) One (1) oil level gauge with low and high level contacts and oil level sight device
(i) Temperature detectors (PT 100) for monitoring the temperature of the anti-friction bearings for protection, alarm and shutdown
(j) One (1) vibration detector system for bearings and gearing for monitoring the vibration for protection, alarm and shutdown
(k) One (1) internal oil piping with stainless steel tubes and cadmium plated fittings

S4.04 WRENCH AND SPECIAL TOOL

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

The Contractor shall submit in “Schedule 6” a detailed description and itemized list of the maintenance tools and instrument whose he proposes to furnish.

S4.05 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 or DIN Standards with the corresponding tolerances.

S4.06 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.

S4.07 SPECIFIED SPARE PARTS

The Contractor shall supply the following specified spare parts.

a) Bearing on high speed shaft	One (1) complete set
b) Bearing on low speed shaft	One (1) complete set
c) Sealing of shafts	One (1) complete set

d) Oil filter	One (1) set
e) Temperature detectors PT 100	Two (2) sets
f) Vibration detector	One (1) set
g) Oil Flow Meter	One (1) set

End of Section

SECTION 5

MECHANICAL AUXILIARY EQUIPMENT

SECTION 5 - MECHANICAL AUXILIARY EQUIPMENT

S5.01 GENERAL

This section specifies the detailed requirements of the design of the systems listed below and of furnishing all plant, labor, equipment, material and supplies necessary for furnishing, installing and testing the equipment, in accordance with these Technical Specification. 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 system. 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.

S5.02 WORK INCLUDED

The equipment covered under this section is for the following systems.

- Cooling water system (if applicable)
- Drainage and dewatering system
- Air compressor unit
- Overhead travelling crane
- Fire extinguisher equipment
- Ventilation and air conditioning equipment

S5.03 CODES AND STANDARDS

All materials, equipment design and methods of all 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)
- American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)
- National Fire Protection Association (NFPA)
- Underwriters' Laboratories Inc. (UL)
- Crane manufacturers Association of America (CMAA)
- European Federation of Handling (FEM)

S5.04 COOLING SYSTEM (IF APPLICABLE)

S5.04.1 GENERAL

The Contractor shall provide cooling system for supply to, if applicable, plant requiring cooling for two (2) Kaplan turbines for main powerhouse and four (4) Axial turbines for emergency channel. Each unit shall consist of one (1) heat exchanger, two (2) water pumps, shaft seal filter, valves, flow relay with flow indication and flow failure alarm, pressure switch, gauges, control equipment, piping, etc.

The cooling water shall be closed system. The heat exchanger shall be submersed in tailwater. The preliminary schematic diagram for cooling system is shown in drawing no. THN-EM-09 Schematic Diagram for Cooling System as attached herewith. The details shown on the drawings shall be taken as the minimum requirement. Finally, the Contractor shall be fully responsible for the detailed design of this system. The cooling water system shall supply for the following.

i) Generator air cooler
ii) Bearing oil cooler
iii) Governor oil cooler

Turbine shaft seal system shall be designed by manufacturer standard.

If any, the bearing oil cooler can be radiator type with electrical fan depending on the design. The Contractor shall design in details of the system together with to specify the flow requirements, size of piping required and the operating head of the system.

S5.04.2 TYPE AND DESCRIPTION

a) Water Pump

The Contractor shall supply two (2) water pumps, one (1) for regular use and the other for stand-by, complete with electrical motors and control for each unit. The pumps shall be centrifugal, horizontal type designed for continuous duty and have the capacity sufficient for cooling flow rate required of the power plant equipment. The pump shall be capable of operating without cavitation or vibration for the entire range of delivery heads encountered for any of the duties for which this pump is designed. The motor specification shall be according to the requirements outlined in S1.09 Electrical Equipment.

b) Heat Exchanger

The heat exchanger, water cooled type, shall be submerged in tailwater. The heat exchangers shall be designed that the differential temperature of inlet and outlet water shall not be less than 2 ^{o}C. The water cooling tubes, tube sheets shall be made of arsenical copper or equivalent corrosion resisting metal to permit low concentration acid injection into cooling system from time to time for cleaning purpose. The scope of supply shall include flanges for coupling heat exchanger's flanges, bolts, nuts and gaskets for pipe connection. The heat exchangers and their piping shall safely withstand a hydrostatic pressure test of one and a half (1.5) times the operating pressure for 30 minutes without leakage.

c) Shaft Seal Filter

If applicable, one (1) shaft seal filter shall be provided at the inlet of turbine shaft seal line. The turbine manufacturer shall specify mesh openings, required capacity and flow rate.

d) Bearing Oil Cooler with Electrical Fan (If Applicable)

The Contractor can supply one (1) bearing air-oil cooler, complete with electrical fans and control for each unit depending on his design. The oil cooler shall be radiator type. The oil cooling tubes, tube sheets shall be made of arsenical copper or equivalent corrosion resisting metal to permit low concentration acid injection into cooling system from time to time

for cleaning. The scope of supply shall include flanges for coupling oil cooler's flanges, bolts, nuts and gaskets for pipe connection. The oil cooler and their piping shall safely withstand a hydrostatic pressure test of one and a half (1.5) times the operating pressure for 30 minutes without leakage.

S5.04.3 PIPING

The Contractor shall be fully responsible for the detailed design of piping. All pipes, flanges, valves, bolts, nuts, washers, etc. shall be made of stainless steel. Piping shall be deemed to include as required, discharge pipe, fittings, guide hangers, supports, anchors, etc.

S5.04.4 INSPECTION AND TEST

After completion of all installation works, the following inspections and tests shall be completely carried out.

- Leakage inspection and test
- Functional test of equipment
- Discharge test

S5.05 DRAINAGE AND DEWATERING SYSTEM

S5.05.1 GENERAL

One (1) sump pit shall be commonly provided for both main powerhouse and emergency channel and located at EL. +179.60 m MSL. This sump pit collects powerhouse seepage water, shaft seal leakage, filter flushing and cleaning and also collects drained water in intake channel and tailrace channel during major maintenance purpose. Two (2) submersible pumps with electrical motor, float switches, piping, valves, local control panel and etc. shall be commonly used for drainage and dewatering purpose.

The drained water in sump pit shall be discharged to tailwater above water flood level. The preliminary schematic diagram is shown in drawing no. THN-EM-10 Schematic Diagram for Dewatering and Drainage System attached herewith.

S5.05.2 TYPE AND DESCRIPTION

Two (2) pumps, directly coupled induction motor driven, shall be submersible type. The design criteria for pump capacity is that two (2) pumps can dewater in intake channel and tailrace channel (after intake stoplog and tailrace stoplog close) within one (1) day. The pump shall be capable of operating without cavitation or vibration for the entire range of delivery heads encountered for any of the duties for which this pump is designed. The motor specification shall be according to the requirements outlined in S1.09 Electrical Equipment.

S5.05.3 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 (all pumps stop, 1st pump start, 2nd pump start and flood alarm) shall be controlled by float switches located inside the drain pit. The float switches shall be of adjustable level type and 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 drain pit.

The details of local control panel and electrical equipment are specified in S1.09 Electrical Equipment.

S5.05.4 PIPING

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 material. Piping shall be included as required, discharge pipe, fittings, hangers, supports, anchors, etc.

S5.05.5 INSPECTION AND TEST

After completion of all installation works, the following inspections and tests shall be completely carried out.

- Leakage inspection and test
- Functional test of float switches
- Pump discharge test

S5.06 AIR COMPRESSOR UNIT

S5.06.1 GENERAL

The air compressor unit shall be supplied with service air of 720 kPa. The Contractor shall determine the compressor capacity, normal operating pressure and pipe size.

S5.06.2 TYPE AND DESCRIPTION

The air compressor unit shall comprise one (1) motorized air cooled compressor with a silencer, intake filter, after-cooler, non-return valve and isolating valve delivering for general use. The compressor shall be arranged to operate by manual push-button control. The system shall be complete with all pipes, fittings/connections, air filters, safety valves, temperature and pressure gauges.

S5.06.3 AIR COMPRESSOR

The air compressor shall be continuously rated and of a reciprocating, air-cooled type. The charging of an air compressor receiver from atmospheric pressure to working pressure can be achieved within 30 minutes.

S5.06.4 INSPECTION AND TEST

After completion of all installation works, the following inspections and tests shall be completely carried out.

- Functional test of equipment
- Pressure test

S5.07 CRANE

S5.07.1 OVERHEAD TRAVELLING CRANE

S5.07.1.1 GENERAL

The scope of supply contains the design, coordination, manufacturing, installation, commissioning and tests. The Contractor shall guarantee a perfect operation of the cranes and shall responsible for the correct installation of the whole system. The supply also comprises all need supports, embedded parts, erection of embedded parts, wiring, etc. which is needed for the correct operation of the cranes. All drawings need for the correct installation of the cranes shall be in the scope of the Contractor.

S5.07.1.2 TYPE AND DESCRIPTIONS

One (1) travelling crane, double girder, shall be supplied for unloading, assembly, erection and maintenance of turbine, generator and other mechanical and electrical equipment in powerhouse. The crane shall travel within the powerhouse. The crane shall be completely fabricated in the workshop and no welds on main structures shall be allowed at the Site.

The Contractor shall provide an electrically driven, pendant controlled, overhead travelling, top running bridge type crane for the powerhouse, together with a set of crane rails, longitudinal travel collector wires and associated equipment, four end buffers for the longitudinal travel and permanently fixed ladder and platform for routine maintenance. The pendant shall be movable horizontally along the crane bridge and located vertically for operation from the floor elevation +201.20 m MSL.

The capacity of the crane to be available for lifting, lowering, traversing and traveling shall not be less than 20 tons and 1.2 times of the heaviest load to be handled during erection and maintenance of the turbine and generator. Finally, the Contractor shall determine and propose the capacity of the crane.

The crane shall be designed, constructed, erected and commissioned in accordance with CMAA or others equivalent standard.

S5.07.1.3 CONSTRUCTION REQUIREMENTS

a) Crane Railway

The Contractor shall supply and installation of all sole plates and anchor bolts for the crane rails, four (4) longitudinal travel buffers and limit switch strikers.

b) Bridge Crane

The bridge shall be single girder. The vertical deflection caused by the rated load shall not exceed length/800 of span.

The complete bridge structure shall be mounted on the end carriages. Each end carriage shall contain wheels which rotate on anti-friction bearings mounted on simply supported axles. The design of each end carriage shall be such that easy inspection and wheel removal is possible.

Four travel buffers shall be attached to the outer bogies, one for each can stop at the end of each crane runway.

c) Longitudinal travel mechanism

The longitudinal travel drive units shall be identically motorized gear units ensuring smooth operation of the longitudinal travel. The high precision gears of these units are run in the oil bath. Each drive unit shall be equipped with the electro-mechanical brake operators according to the sliding rotor principle which shall be capable of being replaced without removing other components. The travel motor is designed as a drive unit for acceleration and safe deceleration of high-inertia load.

d) Traverse drive

The traverse drive shall be operated under all operating conditions with steady and free from vibration or rocking. The traverse drive shall incorporate a motorized gear unit fitted with a spring applied, energized to release brake. Electro-mechanical brake operators according to the sliding rotor principle shall be equipped for each drive unit.

e) Hoisting unit

The hoist motor shall drive the hoist drum by central drive. All gear wheels are oil bath lubricated and mounted on ball bearings totally enclosed with the housing. The hoisting drum shall be steel or cast iron and shall have accurately machined grooving to accommodate the hoisting rope in single layers. The hoisting rope shall be performed non-rotating construction.

The motor torque is transmitted to the reduction gear through a flexible coupling to cushioning high starting torque.

f) Gear box

All gearing other than final drives, shall be enclosed in gearboxes. The gearboxes shall be fitted throughout with ball or roller bearings. The interiors of all gearboxes shall be painted with oil resistant paint.

All bearings and other wearing surfaces shall be provided with means for lubrication, preferably by automatic circulation. Points for lubrication by grease gun shall be suitable for the same make and grade of grease nipple of the all steels, one piece button-head type.

g) Electrical equipment

All electrical equipment shall be suitable for operation from the 380 V, 50 Hz three-phase four-wire supply from the common services switchboard.

All motors shall be half-hour rated for the required duty cycle.

A control and protection panel enclosed in a cabinet, of dust-proof, sheet metal construction, incorporating a hinged door and hinged panel. The equipment shall include an externally operated triple-pole main isolating switch, triple-pole main contactors, triple-pole ganged magnetic overload relays for each motor and all necessary fuses, control switches and

wiring for the motors, control circuits, and one single-phase switched socket outlet. A 'POWER ON' indicating light shall be fitted to the cabinet.

A fall block operated, whole current overhoisting limit switch shall be provided for the hoist. In addition, a shunt type limit switches shall be fitted to the hoist to limit the travel in the 'raise' and 'lower' directions. Shunt type limit switches shall be provided also for the cross-traverse and longitudinal travel motions. All limit switches shall be self-resetting and shall be electrically connected in a manner permitting 'backing out' after tripping.

All crane wiring shall be installed in screwed conduit.

The control pendant shall preferably operate at 24 V but not more than 50 V. The pushbuttons shall return to the off position when pressure is released. The pendant shall include a power on/off switch. The electrical conductors to the pendant shall not be used to support its weight. The pendant shall incorporate a 'POWER ON' indicating light.

S5.07.1.4 INSPECTION AND TEST

Inspection and test shall be performed according to the applicable standard. The Contractor shall furnish test certificate identifying that the crane has been shop tested to 125% maximum load. Upon completion of the crane, the Owner's Engineer may order a full load operating test on the equipment. The Contractor shall furnish the labor and materials required for test and shall at his own expense for correcting the defects in the fabrication and erection.

S5.07.1.5 SPARE PARTS

The powerhouse travelling crane shall be provided with a set of the following spare parts. Furthermore, the crane shall be supplied with a tool set for future maintenance and repair work of its components.

- Two (2) contactors of each type
- One (1) limit switch of each type
- One (1) set of protection fuses of each type
- One (1) set of lamps of each type

S5.07.2 MONORAIL CRANE

S5.07.2.1 GENERAL

The scope of supply contains the design, coordination, manufacturing, installation, commissioning and tests. The Contractor shall guarantee a perfect operation of the cranes and shall responsible for the correct installation of the whole system. The supply also comprises all need supports, embedded parts, erection of embedded parts, wiring, etc. which is needed for the correct operation of the cranes. All drawings need for the correct installation of the cranes shall be in the scope of the Contractor.

S5.07.2.2 TYPE AND DESCRIPTIONS

One (1) monorail crane for intake stoplog and one (1) monorail crane for tailrace stoplog equipped with electrical hoists, crane rail ways, control, wiring and auxiliary components shall be supplied for easier unloading of intake stoplog and tailrace stoplog respectively during

maintenance turbine and generator. The cranes shall be completely fabricated in the workshop and no welds on main structures shall be allowed at the site.

The Contractor shall provide an electrically hoist, crane rail ways, control, wiring and auxiliary components.

Calculations need for the system shall be submitted for Owner Engineer's approval. All components of the cranes shall be designed in accordance with the latest standard and safety regulations. The cranes and crane components shall be designed, constructed, erected and commissioned in accordance with FEM and DIN 15018 or standard industrial type.

The crane capacity and lifting height shall be as below.

- Capacity of 15 tons with minimum lifting height of 16.65 m for intake stoplog monorail crane.
- Capacity of 15 tons with minimum lifting height of 13.55 m for tailrace stoplog monorail crane.

S5.07.2.3 CONSTRUCTION REQUIREMENTS

a) Railways

The rail-ways of the crane shall be installed according to latest FEM or DIN standard. The rail track for the trolley movement shall be designed as a strong sectional beam over the entire length of the stoplogs of two (2) Units. Each crane and railway shall be provided with buffers at both ends. The rail section shall be determined in accordance with FEM provision.

Steel structure and anchor bolts (embedded parts) shall be supplied and installed by the Contractor.

b) Electrical hoist

The trolley cranes shall be designed to lift a maximum load given above and have to be made of structural steel construction forming a rigid set. The motor for travelling as well for the hoisting mechanism of the crane shall be of a squirrel cage type equipped with brake motor system (holding 150 % of the full load torque). Furthermore, limit switches shall be installed for the hoisting as well the travelling of the monorail crane. The reduction gear shall be fitted with ball or roller bearings, running in the oil bath within an oil and dust proof gearbox equipped with sight gauge glasses.

Motor for crane drive shall be designed according to FEM or DIN standard and IP 44 protection. All other components of the crane shall be according to latest FEM or DIN standard.

c) Electrical equipment

All electrical equipment shall be suitable for operation from the 380 V, 50 Hz three-phase four-wire supply from the common services switchboard.

All motors shall be half-hour rated for the required duty cycle.

A control and protection panel enclosed in a cabinet, of dust-proof, sheet metal construction, incorporating a hinged door and hinged panel. The equipment shall include an externally operated triple-pole main isolating switch, triple-pole main contactor, triple-pole

ganged magnetic overload relays for each motor and all necessary fuses, control switches and wiring for the motors, control circuits, and one single-phase switched socket outlet. A 'POWER ON' indicating light shall be fitted to the cabinet.

A fall block operated, whole current overhoisting limit switch shall be provided for the hoist. In addition, a shunt type limit switches shall be fitted to the hoist to limit the travel in the 'raise' and 'lower' directions. All limit switches shall be self-resetting and shall be electrically connected in a manner permitting 'backing out' after tripping.

All crane wiring shall be installed in screwed conduit.

The control pendant shall preferably operate at 24 V but not more than 50 V. The pushbuttons shall return to the off position when pressure is released. The pendant shall include a power on/off switch. The electrical conductors to the pendant shall not be used to support its weight. The pendant shall incorporate a 'POWER ON' indicating light.

S5.07.2.4 INSPECTION AND TEST

Inspection and test shall be performed according to foregoing standards. The Contractor shall furnish test certificate identifying that the crane has been shop tested to 125% maximum load. Upon completion of the crane, the Owner's Engineer may order a full load operating test on the equipment. The Contractor shall furnish the labor and materials required for such test and shall at his own expense for correcting the defects in the fabrication and erection.

S5.07.2.5 SPARE PARTS

Two (2) monorail cranes shall be provided with a set of the following spare parts. Furthermore, the crane shall be supplied with a tool set for future maintenance and repair work of its components.

- Two (2) contactors of each type
- One (1) limit switch of each type
- One (1) set of protection fuses of each type
- One (1) set of lamps of each type

S5.08 FIRE EXTINGUISHER EQUIPMENT

S5.08.1 GENERAL

The Contractor shall provide rechargeable portable CO_2 extinguishers and dry chemical extinguishers complete with wall mounting brackets and other accessories. The amount of extinguishers to be installed shall be as below.

	CO_2 extinguishers	**Dry chemical extinguishers**
- Control room (EL. +201.20 m MSL.)	1	2
- Service area (EL. +201.20 m MSL.)	1	2
- Switchgear room (EL. +195.60 m MSL.)	2	-
- Switchgear 2 room (EL. +195.60 m MSL.)	2	-
- Battery room (EL. +195.60 m MSL.)	1	-
- Turbine/generator floor (EL. +187.20 m MSL.)	1	2
- Mechanical room (EL. +187.20 m MSL.)	-	1

Their final mounting location shall be proposed to Owner's Engineer during engineering period.

S5.08.2 TYPE AND CONSTRUCTION

Dry chemical extinguishers shall be of a multi-purpose type suitable for Class A, B and C fires with TIS. 332-1994. While, CO_2 extinguishers shall be of a multi-purpose type suitable for Class B and C fires with UL approval. Each extinguisher shall be a minimum 6.8 kgs (15 lbs.) capacity (weight of chemical).

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.

S5.09 VENTILATION AND AIR CONDITIONING EQUIPMENT

S5.09.1 GENERAL

The ventilation and air conditioning equipment shall be furnished and installed in accordance with the drawings and specifications. Prior to execution of the work, the Contractor shall submit installation drawings that show all details to the Owner's Engineer for approval.

S5.09.2 VENTILATION EQUIPMENT

The Individual ventilated fans shall be provided at each room as below.

- Control room (EL. +201.20 m MSL.)	one (1) set
- Office room (EL. +201.20 m MSL.)	one (1) set
- Toilet room (EL. +201.20 m MSL.)	one (1) set
- Switchgear room (EL. +195.60 m MSL.)	one (1) set
- Switchgear 2 room (EL. +195.60 m MSL.)	one (1) set
- Battery room ceiling (EL. +195.60 m MSL.)	one (1) set
- Mechanical room (EL. +187.20 m MSL.)	one (1) set
- Store room (EL. +187.20 m MSL.)	one (1) set

The fan shall generate low noise and vibration in operation. The detailed calculation of air change per hour required for ventilation in each room shall be submitted during engineering period.

S5.09.3 AIR CONDITIONING EQUIPMENT

a) General

The air conditioner shall consist of compressor, motor, fan, condenser, cooling coil, etc. and shall include safety device, operation panel and other accessories, and shall generate low noise and vibration in operation. The modern split type air conditioning shall be provided at each room as below.

- Control room (EL. +201.20 m MSL.)	two (2) sets
- Office room (EL. +201.20 m MSL.)	one (1) set
- Switchgear room (EL. +195.60 m MSL.)	two (2) sets
- Switchgear 2 room (EL. +195.60 m MSL.)	two (2) sets

The detailed calculation of heat load for each room shall be submitted during engineering period.

b) Compressor

Compressor shall be hermetic type with internal vibration isolator designed for R410a or R32 refrigerant.

Compressor shall be complete with thermal overload and over-current protection, high and low pressure switches, crankcase heater and recycling guard timer.

c) Housing of indoor unit

The housing of indoor unit shall be made of galvanized steel sheet 1.0 mm. thick or more reinforced sufficiently.

d) Outdoor unit (Condenser)

Outdoor unit shall consist of finned coil, fan, motor and housing. The coil shall be copper pipe. The fin shall make of aluminum sheet treated by chromate method or coated with acrylic resin to prevent from corrosion. The fin shall be provided with protection not to be damaged. The housing shall be made of galvanized steel sheet 1.0 mm. thick or more coated with acrylic resin or melamine baked paint or epoxy resin, etc. as the rust resistance.

S5.10 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 S1.05 Control and Auxiliary Power Supplies.

S5.11 ELECTRICAL EQUIPMENT

All electrical equipment associated with auxiliary mechanical systems and equipment herein specified shall meet the requirements in S1.09 Electrical Equipment.

S5.12 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 S1.13 Painting.

S5.13 NAMEPLATE

All new equipment shall be identified, and all nameplate wording shall be subject to Owner's Engineer. Nameplates shall be in accordance with the specifications outlined in S1.13 Nameplate and Marking.

S5.14 INSPECTION AND TESTS

S5.14.1 GENERAL

All auxiliary mechanical systems shall be subject to inspection and testing as specified in S1.17 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. The Contractor also shall provide all necessary special instrumentation for tests.

S5.14.2 TYPE TEST

Type tests may be offered by the Contractor as specified in S1.17 Inspection and Tests-Electrical/Mechanical, provided the Contractor gives evidence to Owner's Engineer as to the similarity of the equipment tested and the equipment supplied.

S5.14.3 SHOP TEST

The equipment shall be subjected to shop tests 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 clause **S1.17** Inspection and Tests Electrical/ Mechanical.

b) Hydrostatic Test

Hydrostatic tests shall be as specified in clause **S1.17** Inspection and Tests-Electrical/ Mechanical.

c) Shop Test

Shop tests as specified in clause **S1.17** Inspection and Tests Electrical/Mechanical.

S5.15 SPECIFIED SPARE PARTS

The Contractor shall submit lists of specified spare parts, which are priced separately. The spare part lists shall be available to be purchased at the option of Owner's Engineer for applicable unit prices. Expected delivery schedule for each spare part shall be submitted.

End of Section

SECTION 6

ELECTRICAL AND CONTROL SYSTEM EQUIPMENT

SECTION 6 - ELECTRICAL AND CONTROL SYSTEM EQUIPMENT

S6.01 GENERAL REQUIREMENT

This section describes the requirement of electrical and control system that shall be applied for the Thong Noi Diversion Weir Hydropower Project. The design, manufacturing, installation and testing for all equipment, materials, devices and components shall be the responsibility of the contractor in accordance with this technical specification. Material and equipment not covered by this technical specification shall be subject to acceptance by the owner engineer.

S6.02 SCOPE OF WORK

The scope of work shall comprise of engineering, procurement and construction of the electrical and control system equipment for the Thong Noi Diversion Weir Hydropower Project. The Contractor's scope of work shall include design and engineering, material procurement, manufacturing, factory testing, packing and transport to site, erection, commissioning, demonstration testing, trail operation, performance testing, onsite training, quality control, overall project coordination and management as well as site supervision and management including the following:

(1) Low voltage generators and auxiliary equipment: including excitation system, generator control panel, protective relay for generator and excitation system, generator's surge protection and neutral grounding equipment.

(2) Low voltage switch boards : LV switchgear including protection and metering system for generators feeders, main distribution board for LV auxiliary load and emergency diesel generator, AC distribution board for each generator unit, DC distribution board, and Sub-distribution boards.

(3) 24 kV insulated switchgear : HV01, HV02, HV1, HV2, HV3, HV4.

(4) Protection and Metering System: for generator, low voltage switchgear, main distribution board, AC distribution board, DC distribution board, step-up power transformer, emergency diesel generator and related electrical equipment.

(5) 22kV equipment, protection and metering for 22kV system in accordance with the latest PEA grid code: one sets of disconnecting switch with fuse including surge arrester at tie-in point (nearby PEA's 22kV dead end pole) and three sets of disconnecting switch with fuse including surge arrester at plant boundary, revenue meter and instrument transformers, power quality meter and instrument transformers, and protective relay for 22kV system as required by PEA grid code.

(6) 380V and 220V Motors: for auxiliary equipment and balance of plant.

(7) One set of batteries and battery charger.

(8) One set of UPS system.

(9) Cables and Raceway: power cables, communication cables, control cables, instrument cables and special cables as required by system requirement.

(10) Raceway: conduit, cable tray, cable trench, ductbank, manhole and handhole.

(11) Grounding and Lightning protection system.

(12) CCTV system.

(13) Fire detection and alarm system.

(14) PLC system and SCADA system.

(15) Plant control system.

(16) Instrumentation system.

(17) Required spare part.

(18) Onsite training course: operation and maintenance.

(19) Other furniture and apparatus to full fill normal operation and maintenance of the small hydro-power plant.

(20) Construction service including construction management, scheduling, construction equipment, and manufacturer's field services.

(21) Permission work for PEA's 22kV interconnection.

(22) Provide certified drawings and documents signed by authorized/license engineers for electrical, communication and control system in order for Owner to obtain the permits and /or approvals such as PEA's 22kV interconnection permit.

(23) All as-built drawings with certified by authorized/license engineers, engineering information, manufacturing information, operation/maintenance instruction manual.

(24) All required tools and test equipment.

(25) Commissioning and start-up spare parts.

(26) Consumable for construction, star-up, testing and initial operation such as electricity, water, fuel oil.

The Contractor shall propose the recommended spare part and apparatus for electrical and C&I equipment as the "option".

S6.03 TERMINAL POINT

The terminal point for electrical system shall be tied-in at 22kV pole nearby plant boundary.

The Contractor shall coordinate with the Provincial Electricity Authority to determine the connection points. The operating costs incurred belong to the contractor.

S6.04 CODES, STANDARDS, REGURATION AND THAI LAW

system shall be comply in all respects with all relevant law and regulations of the Government of Thailand and with all applicable local codes and ordinance. Except as provided in the specifications, all material, equipment, design, manufacturing, fabrication, installation and testing shall conform to the latest applicable standards contained in the following list of internationally accepted standards.

- The Antifriction Bearing Manufacturers Association (AFBMA)
- American National Standards Institute (ANSI)
- American Society for Testing and Materials (ASTM)
- American Society of Mechanical Engineers (ASME)
- American Petroleum Institute (API)
- British Standard (BS)
- Edison Electric Institute (EEI)
- Engineering Institute of Thailand (E.I.T)
- German Institute for Standardization (DIN)
- Insulated Cable Engineers Association (ICEA)
- International Electrotechnical Commission (IEC)
- Institute of Electrical and Electronics Engineers (IEEE)
- Instrument Society of America (ISA)
- International Organization for Standardization (ISO)
- Illuminating Engineering Society (IES)
- Japanese Industrial Standard (JIS)
- National Association of Corrosion Engineers (NACE)
- National Electrical Code (NEC)
- National Electrical Manufacturers Association (NEMA)
- National Electrical Safety Code (NESC)
- National Fire Protection Association (NFPA)
- Occupational Safety and Health Act (OSHA)
- Scientific Apparatus Makers Association (SAMA)
- Thai Industrial Standards (TIS)
- Underwriters' Laboratories (UL)

Design and construction shall be as required by the above-mentioned codes and standards except where modified or supplemented by these specifications. Other recognized standards shall be utilized as required, to serve as design, fabrication and construction guidelines when not in conflict with the above-mentioned standards. The codes and industry standards used for design, fabrication and construction shall be the codes and industry standards, including all addenda, in effect as of the issuance date of Letter of Intent.

S6.05 SERVICE CONDITION

All the equipment shall be design and manufactured for its particular location for continuous operation. Specifically, all equipment to be installed indoors shall be designed and manufactured for satisfactory continuous operation at an ambient temperature of 40ºC and all equipment to be installed outside shall be designed and manufactured for satisfactory continuous operation at an ambient temperature of 45ºC. Equipment supplied between ceilings and roofs shall be designed for satisfactory operation at an ambient temperature of 60ºC.

S6.06 ELECTRICAL DESIGN CRITERIA

This item describes the design criteria that shall be used for all electrical works related to the small hydro-power plant project. Electrical system design shall be the responsibility of the Contractor in accordance with the technical specifications, one-line diagrams and drawings. All equipment ratings, capacities and sizes indicated in the specifications and on the drawings are minimum requirements and shall be determined by the Contractor.

The design and engineering of the electrical installation shall satisfy all statutory requirements of the relevant local authorities.

(1) Electrical System Voltage
- High-voltage system : 22 kV, 3 phase, 3 wire, 50 Hz
- Low-voltage system : 400 V and below, 3 phase, 4 wire, 50 Hz

(2) Operational Voltage of Equipment Voltage
- Power transformer : As specified in the drawings
- Generator : 3,300 V, 3 phase, 3 wire, 50 Hz (Main Powerhouse)
- Generator : 400 V, 3 phase, 3 wire, 50 Hz (Emergency Channel)
- Low-voltage 3 phase motor : 380 V, 3 phase, 3 wire, 50 Hz
- Low-voltage 1 phase motor : 220 V, 1 phase, 2 wire, 50 Hz
- Lighting system : 380/220 V, 3 phase, 4 wire, 50 Hz
- Welding outlets : 380V, 3 phase, 4 wire, and earth, 50 Hz
- General outlets : 220 V, 1 phase, 2 wire, and earth, 50 Hz
- AC supply for control system : 220V, 1 phase, 2 wire, 50 Hz
- DC supply for control and instrument : 125 V, DC 2 wire

Low voltage earthing system shall be of TN-S, the neutral and protective conductor shall be separated in a TN-S system.

(3) System Earthing
- 22 kV system: Solidly grounded
- 400 V system: Solidly grounded (TN-S)

(4) Voltage Drop

The maximum allowable voltage drops shall be as follows:
- AC/DC Power feeders 5%
- Motor cables at full load 5%
- Lighting circuits 3%
- UPS circuits 3%
- Motor cables during starting 15%

(5) Degree of protection (IP) for equipment enclosure defined by IEC 60529
- Motor: outdoor IP55, indoor IP54
- Switchgear: indoor IP41
- Distribution panel: outdoor IP55, indoor IP31
- control panel: outdoor IP55, indoor IP31
- Local control station: outdoor IP65, indoor IP54
- Outlet: outdoor IP55, indoor IP20
- Lighting panel: outdoor IP55, indoor IP42
- Junction boxes: outdoor IP55, indoor IP42

S6.07 CONTROL AND PROTECTION SYSTEM DESIGN CRITERIA

S6.07.1 CONTROL SYSTEM

This items describes of the design criteria that shall be used for control, instrument and protection system works related to the small hydro-power plant project. The design shall be the responsibility of the Contractor in accordance with the technical specified herein, The control, instrumentation, supervisory, mechanical and electrical protection device shall be designed and provided for safe and reliable operation of small hydro power plant with automatic control and supervision of turbine-generator units, speed governor, transformers, switchgear, diesel generator, station auxiliaries and mechanical auxiliary equipment. The control system shall comprise a number of programmable logical controllers (PLC), a speed governor system, an excitation including automatic voltage regulator, a digital protective relay and synchronizing system. This PLC shall be connected to each controller or any proprietary control device by high speed data communication device and network.

The operation based for this plant shall be consist of automatic mode, step by step mode and manual mode. A typical automatic mode shall be a programming control sequence stored in the PLC. The normal control shall be initiated at operator station in the control room for start/stop unit. For maintenance and testing purposed shall be done at local control board. The control functions shall include supervising and monitoring the machine conditions, recording the sequence of events, fault and alarm events, permissive and interlocking function, providing integration of historical data storage and retrieval and trending display, bar chart display and operator guidance messages and annunciation system. The firewalls and data securities method shall be implemented in control system. The OPC server/client with database for executive information system shall be provided in order to support remote monitoring.

In order to supervise the operator to control the units, the Contractor shall provide a real time data to display on LCD monitor of operator station as a minimum of the following items, ie., Unit MW, MVAR, energy kWh, Unit Voltage, Current, Frequency, status of PLC, network devices, status of governor, status of exciter, water flow, water level, temperature of stator winding and etc.

The control systems shall be designed for detection and safe shutdown of the power plant under unsafe operating conditions and when single failure of control device or power source. In case of processor or controller failure, where a single controller has been specified to serve without a backup, a system response consisting of transfer of function to manual, or a shutdown of running equipment may be allowable. All such failures, however, shall be alarmed. The adequate instrument with analog 4-20mA output, switch contact shall be provided to support the interlock and protection. A red mushroom head emergency pushbutton with

double action shall be provided in control room for emergency shutdown when the normal shutdown sequence is incomplete or in case of emergency.

The equipment shall be provided based on the Technical Specifications defined herein.

- Two (2) Operator stations with LCD monitor including software licensed for control, operation and monitoring function in English.
- One (1) Engineering station (Laptop computer) including software tool for engineering work and testing.
- Programmable logical controller (PLC) 2 sets including software
- Local control unit cubicle for each unit and common of electrical and auxiliary equipment. Annunciation windows on each cubicle at least 2x16 windows with test lamp, remote/local selector switch, emergency trip push button with cover. Fan, lighting with door switch, heater with thermostat for humidity control.
- One (1) Sequence of Event (SOE) server with one millisecond input card for SOE point at least 200 point for the whole plant for 2 years recording. The historical data storage and retrieval function shall be included to store, retrieve, and display all measurement data, alarms and report
- Automatic/Manual Synchronization system including synchro scope, synch check relay completed with metering and accessories for two unit.
- Digital protective relay system
- Local Area Network (LAN) Ethernet TCP/IP 10/100/1000 Mbps including network switching.
- Power supply from 230 AC UPS.
- One Master clock with antenna and lightning arrester, one clock indicator
- Network color laser printer supported A3 size with duplex printing function.
- Operator control desk for installation of all monitors and chairs
- Marshalling cabinet for cable connection
- Instrumentation with 4-20 mA signal transmission and local display. The shut off valve for terminate between instrument and process pipe shall be provided for all instrument. RTD pt100 Ohm shall be provided for temperature measurement. In case of switch type be applied, the contact shall be SPDT. Instrument tag name stainless steel plate shall be hang or installed the stainless steel tag name plate for each instrument.
- CCTV system for surveillance purpose, three (3) IP fixed indoor type, four (4) IP PTZ outdoor type.

S6.07.2 CONTROL MODE

The system shall operate from operator station in control room (remote) or from turbine control panel (local). The selection shall be done at turbine control panel, The Contractor shall provide the selector switch on turbine control panel as a local/remote switch.

The operator shall be able to select one of the following control modes.

a. Manual mode : The unit and associated equipment shall be manually controlled at remote control and control panel of each equipment.
b. Auto mode : All unit control sequences shall be carried out automatically from standstill through synchronized once initiated by an operator from operator station in control room.
c. Step by step mode : The operator shall be able to “step” through each step of the Auto sequences by initiating each step.

S6.07.3 UNIT CONTROL SEQUENCE

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.

When Normal shutdown, 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 shutdown by sequence which determined by generator and governor supplier.

Emergency shutdown by operator, A red mushroom head emergency pushbutton with double action shall be push when emergency case or incomplete of normal shutdown

S6.07.4 UNIT SYNCHRONIZATION

This item specifies the minimum requirements to the design of three phase synchronous generators for small hydro-power plant. Synchronization must be conducted at the LV generator circuit breaker to connected generator to PEA's grid system via step-up transformer with safely operation. Only one automatic synchronizing package for both units shall be performed at HMI and OWS. The automatic synchronizing package shall allow one click for a dry-contact closure to initiate the automatic synchronizing sequence to begin culminating a short time later without any further operator input required.

S6.07.5 PROTECTION SYSTEM

The protective relays shall be microprocessor-based and consisting of multi-functional digital relays. Relays and protection circuits shall be rated for 125 VDC and shall be supplied from separate dedicated fused DC circuits. . Loss of supply relays shall monitor and shall alarm when loss of DC. All VTs and CTs circuits shall be supplied with test switches for isolation and tests. The settings for the relay functions shall be programmed via laptop computer using software supplied by the manufacturer.

Minimum protection functions shall be provided as the following but not be limited to the following, then protection shall be complied with PEA connection code.

-	Generator	Overcurrent
		Ground fault overcurrent
		Directional overcurrent
		Directional ground fault overcurrent
		Reverse power
		Over/Under frequency
		Over/Under voltage
-	Step-up Transformer	Over current and short circuit protection
		By disconnecting switch with fuse
-	22kV Distribution line	Over current and short circuit protection
		By disconnecting switch with fuse
		Zero sequence over voltage relay

S6.07.6 REVENUE METERING

The revenue meter shall be provided and installed at the interconnection point. The revenue meter could meter the capacity and/or energy sold to PEA and specification shall be complied with PEA standard, accuracy class shall be 0.5 at least, the instrument transformer that connected to the revenue meter must not be jointly connected to other meters or relays

S6.07.7 POWER QUALITY METER

For efficient inspection and regulation of power quality, as per PEA grid connection code, the Power Quality Meter shall be provided and installed at the electrical room or at the interconnection point as per PEA requirement.

Power quality meter shall record information such as voltage, frequency, electrical power, power factor, THDv, THDi, Pst, Plt, etc. and PEA must be able to observe and inspect the real-time power quality data via communication systems.

S6.07.8 SCADA SYSTEM

All control system shall be monitored by SCADA system as specified in drawings.

S6.08 DRAWINGS AND DOCUMENTS

The drawings/documents for electrical and control systems shall include the following as a minimum:

- Overall single line diagrams
- Single line diagrams
- Logic diagrams and flow chart
- Control configuration diagrams
- Schematic diagrams
- Wiring diagrams
- Cable schedules
- Raceway schedules
- Motor and load lists
- Input/Output lists
- Instrument lists
- PLC hardware and software lists
- Drawing for graphic display for control system
- Equipment Instruction manual
- Equipment catalog
- Plan layout drawings
- Outline and assembly drawings
- Overall system design concept
- System block diagram
- Cabinet arrangement and layout
- Control room layout
- Lightning Protection and Grounding System drawings
- Electrical room layout
- Detail sizing calculation
- Protective relay setting calculation and coordination curves

- Typical installation drawings
- Instrument hook up drawings
- Plant control system operation and maintenance manuals
- Software logic
- Training document
- Spare part document

Calculations shall be submitted covering load flow studies, short circuit, transient and steady state voltage drops, prospective phase and earth fault, insulation coordination and equipment sizing study.

The Contractor shall coordinate, calibrate and set all field protective relays in the system and shall provide Owner with coordination curves, tabulation of recommended settings for relays, breakers, and transformer taps and complete manufacturers' data and site test reports on all protective devices.

S6.09 GENERATOR AND AUXILIARY EQUIPMENT

S6.09.1 GENERAL REQUIREMENT

This section specifies the minimum requirements to the design of three phase synchronous generators for small hydro-power plant including the auxiliary equipment required for excitation, bearing lubrication, generator cooling and for monitoring the windings temperatures etc.

The generator shall operate satisfactorily in parallel with other generating units. Generator construction shall conform to IEC/ANSI standards or equivalent for hydro-turbine driven synchronous generators. The generator shall be provided with a complete brushless excitation system

Generator shall produce electricity at 3,300V (main powerhouse) and 400V (emergency channel) on its terminal and step-up to 22 kV level via step-up power transformer for interconnecting with PEA’s distribution line system in order to export electric power into PEA’s grid system.

The layout arrangement, the generator capability curve and efficiency curve which are consistent with the guarantees relating to efficiency and output of Generator for main powerhouse **shall be submitted together with the Bid. Failure to submit will reject the Bid Proposal.**

S6.09.2 RATING CHARACTERISTICS

(1) Main Powerhouse
   a. Number of units: 2
   b. Voltage: 3,300 V
   c. Rated output, not less than: 1,400 kVA
   d. Rated power factor, lagging: 0.8
   e. Rated frequency: 50 Hz
   f. Guaranteed efficiency: Not less than 95% at 0.8 pf lagging
   g. Number of phases: 3

h. Voltage range at rated output, rated speed, rated power factor: ± 5%
i. Rated speed in rpm: To be defined by the Contractor
j. Stator winding: Copper
k. Stator winding connection: Star
l. Stator and Rotor winding insulation: Class F or higher

(2) Emergency Channel
a. Number of units: 4
b. Voltage: 400 V
c. Rated output, not less than: 280 kVA
d. Rated power factor, lagging: 0.98
e. Rated frequency: 50 Hz
f. Guaranteed efficiency: Not less than 94% at 0.98 pf lagging
g. Number of phases: 3
h. Voltage range at rated output, rated speed, rated power factor: ± 5%
i. Rated speed in rpm: To be defined by the Contractor
j. Stator winding: Copper
k. Stator winding connection: Star
l. Stator and Rotor winding insulation: Class F or higher

S6.09.3 TEMPERATURE RISE

The temperature of the armature windings will be determined by embedded resistance type temperature detectors. The temperature of the field winding will be determined by the resistance method.

The temperature rise of the magnetic core and other parts in contact with or adjacent to insulation or windings shall not exceed 80ºC determined by thermometer method or embedded resistance type temperature detector.

S6.09.4 ELECTRICAL CHARACTERISTICS

a. Unsaturated value of direct-axis reactance (Xdu) shall be as low as possible, consistent with economic design.
b. Unsaturated value of direct-axis transient reactance (X'du) shall be as low possible, consistent with economic design
c. Saturated (rated voltage) value of direct-axis sub-transient reactance (X"d) shall be as high as possible, consistent with economic design.
d. Short circuit ratio shall not be less than 0.8
e. Nominal ceiling voltage of excitation system, in percent of rated load field volts, shall not be less than 150 %
f. Spare excitation capacity above nominal requirement shall not be less than 10%
g. 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%. The specific time (milli second) to full fill this requirement shall be defined by the Contractor.
h. Total Harmonic Distortion (THD) of line to line voltage, on open circuit and at rated speed and voltage, shall not greater than 5%
i. Deviation factor of wave form, measured in percent from line-to-line on open circuit at rated voltage and frequency, shall not more than 5%

S6.09.5 MECHANICAL CHARACTERISTICS

a. Flywheel effect (J) of rotating parts of the generator include external flywheel (if applicable) shall be defined by the Contractor as required by the turbine manufacturer.
b. Maximum runaway speed (subject to verification by turbine manufacturer) shall be defined by the Contractor.
c. Ratio of first bending critical speed to maximum runaway speed not less than 1.25
d. Minimum duration of operation at maximum runaway speed shall be 30 minutes.
e. Direction of rotation, as viewed from turbine side shall be clockwise
f. Maximum temperature of cooling water for oil and air-cooling system (if applicable) shall be 30^{o}C.

S6.09.6 EFFICIENCY

The guaranteed efficiency at rated power output and rated voltage, power factor and frequency, including losses in the excitation system and excitation transformer (if applicable) as well as in the bearings shall not be less than as specified in clause **S6.09.2**.

S6.09.7 TYPE AND DESIGN CRITERIA

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 Contractor shall propose the procedure for installation of the turbine and/or generator with alignment method in the Bid proposal as well as procedure of assembly and disassembly to be done during maintenance period. Each generator shall meet the recommendations of IEC 60034 Standards for electrical rotating machinery. Complete information including supporting calculations regarding the maximum stresses used in the design shall be furnished to the Engineer for approval.

S6.09.8 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. The generator stator winding shall be star connected with neutral point brought out suitable for grounding method to a neutral cubicle. The stator windings shall be made of copper, multi-turn or singe 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 (platinum 100 ohms at 0ºC) shall be furnished and installed in approved locations of the stator winding.

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.

S6.09.9 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.

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 wounded 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.

S6.09.10 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.

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.

S6.09.11 BEARINGS

The bearing can be sleeve type or anti friction bearing. These bearings shall be guaranteed for continuous working for one hundred thousand (100,000) hours and shall be of proven design and performance. The temperature of the bearing metal shall not exceed 75^{o}C for alarm and 80^{o}C for trip when the temperature of cooling water is 30^{o}C. 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 30 minutes.

Force Lubrication Type Bearing (if required), The oil pumping set shall consist of two (2) oil pumps, one for normal operation and the other for stand-by. The oil pumping set shall be complete with oil tank, necessary piping, isolating valves, duplex filter, filter blocking device, level indicator, level switches, thermometers, pressure switches or oil flow failure switch

Dial type thermometers complete with two (2) 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. Water cooled bearings shall have high or low water level alarm/trip contacts.

S6.9.12 COOLING SYSTEM

The generator shall be self-ventilated, open-circuit air cooled system and the protection will be IP 23. 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.

S6.9.13 EXCITATION SYSTEM

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 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, or 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.
c. 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, that time required for the generator back-up protection to clear the short-circuit.
d. Operating at low loads for supplying power to the station service system in case there is no power from 22 kV line (with line switch or line circuit breaker opened).
e. Unless the field of exciter is supplied from PMG, a provision for field flashing of the rotating exciter for startup purpose is requires

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. Joint voltage (or var control) (Not applicable)
f. 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
g. AVR shall be suitable for operating with an automatic start/stop control including automatic synchronization system

    For brushless exciter, the AC power for operation of the AVR shall be supplied by 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.

S6.09.14 AUTOMATIC VOLTAGE REGULATOR

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.

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.

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.

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.

S6.09.15 NEUTRAL GROUNDING CUBICLE

The generator neutral through a resistor can be acceptable. The Contractor shall furnish a metal-enclosed neutral cubicle with access doors. Cable terminal compartment, complete with cable supports and terminals, suitable for cable entry through the top of the cubicle.

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.

A current or voltage transformer (according to the Manufacturer's practice) for the supply of the stator earth fault protection relay shall be provided.

Neutral grounding shall be in accordance with IEEE Std C62.92. Calculation sheets shall be submitted for approval.

S6.09.16 INSTRUMENT 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 $0^{o}C$ 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.

S6.09.17 FACTORY TEST

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.

a. No-load characteristic
b. Short-circuit characteristic
c. Copper and iron losses measurement
d. Heat run under short-circuit conditions at rated current
e. Testing the rotating field
f. Shaft voltage
g. Overspeed test
h. Winding test
i. Stator/rotor high-voltage-test
j. Noise level

The following Performance Tests on generator shall be done at factory

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 guaranteed output 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.
c. The above Performance Tests shall be applied for one (1) generator for each model.

The excitation system for each generator 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

S6.09.18 SITE TEST

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 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 ultra violet 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 40ºC. 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;
    2. Accuracy of the excitation control system during changes of:
        (i) Load.
        (ii) Ambien 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. Generator trial run test for 48 hours by connected to PEA grid system.

S6.09.19 SPECIAL TOOLS

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.)

S6.10 24 KV INSULATED SWITCHGEAR

S6.10.1 STANDARD

The switchgears and the relevant equipment shall be designed, manufactured and tested according to the latest version of the following standards.

-	IEC 62271 PART 1	:	Common Specification for High-Voltage Switchgear and Control Gear Standards
-	IEC 62271 PART 100	:	High-Voltage Alternating-current Circuit Breakers
-	IEC 62271 PART 102	:	Alternating Current Disconnector and Earthing Switches
-	IEC 62271 PART 200	:	Metal Enclosed Switchgear For MV
-	IEC 60044 PART 1	:	Current Transformers (CT) or IEC 61869 Part 2, CT Protection Class 5P20
-	IEC 60044 PART 2	:	Inductive Voltage Transformers (VT) or Potential Transformer (PT) or IEC 61869 Part 3
-	IEC 60376	:	Specification and Acceptance of New Sulfur Hexafluoride (SF6)
-	IEC 60529	:	Degrees OF Protection provided By Enclosures (IP Code)
-	IEC 60255	:	Electrical Relays
-	IEC 60480	:	Guide to the Checking of Sulfur Hexafluoride (SF6) Taken from Electrical Equipment

S6.10.2 GENERAL REQUIREMENT

(1) Switchgears shall be Hermetically tight, welded switchgear vessel made of stainless steel and maintenance-free.

(2) The SF6 22kV switchgear covered by this Specification (i.e. materials, individual parts and completed units) to be designed, manufactured and tested according to the requirements of this specification and according to the Standards referred to clause **S6.10.1**.

(3) Switchgears shall be equipped with necessary, motors, protection relays, CTs, capacitive indicators, fault indicators and etc. that can support remote monitoring from SCADA.

(4) The Contractor shall have a valid ISO9001:2000 quality management system certificate for the goods offered

(5) Protection relay shall meet IEC 60255 and IEC 61850 standards.

(6) Cable termination shall meet EN 50180 or EN 50181 standards.

S6.10.3 TECHNICAL REQUIREMENT

(1) Medium voltage gas Insulated switchgear single bus or medium voltage switchgear or gas insulated switchgear (GIS) single bus shall meet the following requirements :

(a) Metal enclosed type hermetically sealed in SF, filled container.

(b) All medium voltage switchgear cubicles, high voltage live part shall be contained in SF5 gas insulated metallic and earthed enclosures. Busbar part may or may not be in the same gas tank. In case of busbar not in gas tank, busbar insulated tank must be in contact safely while power is being supplied.

(c) Electrical properties of medium voltage switchgear cubicle shall be as follows:

- Rated Voltage	:	24 kV
- Rated Current	:	> 800A
- Rated Power Frequency Withstand Voltage	:	50 kV
- Rated Impulse Withstand Voltage	:	125 kV
- Rated Short-Time withstand Current (3 sec)	:	> 25kA
- Rated Internal Are Current IAC A FLR (1 sec)	:	> 25kA
- Rated Short Circuit Making Current	:	> 63 kA
- Degree of Protection of Medium Voltage Live Parts	:	> IP64
- Degree of Protection of Enclosure	:	> P3X

(d) Gas tank shall have pressure gauge or gas monitoring system for checking the quantity of gas container. and have aux. contact to warn when gas SF6 pressure is lower than specified.

(2) Circuit Breaker shall be fixed circuit breaker & vacuum circuit breaker type for cable feeders and transformer feeders with Spring charge manual/motor operated mechanism and earthing switch as three position disconnectors by manual/motor operation and shall be rated as follows:

- Rated Voltage	:	24 kV
- Rated Lightning Impulse Withstand Voltage	:	125 kV
- Rated Power Frequency Withstand Voltage	:	50 kV
- Rated Frequency	:	50 Hz
- Rated Normal Current (Incoming Feeder)	:	> 800A
- Rated Normal Current (Outgoing Feeder)	:	> 630A
- Rated Short Circuit Breaking Current (3 sec.)	:	> 25 kA
- Rated Short Circuit Making Current	:	> 63 kA
- Tripping and Closing Coil ใช้กับไฟฟ้า	:	110 VDC
- Rated Operating Sequence	:	0-0.3 -sec-CO-3 min-CO
- Rated Total Opening Time	:	> 65 ms.
- Closing Time	:	> 75 ms.

(3) Multifunction Protection Relay is a microprocessor base system protection type with the following features:

(a) Able to configure, setting and metering through personal computer.

(b) Power Supply: 220 Volts.

(c) Built-in communication interface according to IEC 61850.

(d) Support Fault Locator system.

(e) Incoming and Outgoing protection shall have the following protection systems:

- SHORT CIRCUIT : DIRECTIONAL OVERCURRENT (67) / OVERCURRENT (50/51)
- EARTH FAULTS : DIRECTIONAL EARTH (67N)/ EARTH FAULTS (50N/51N)
- OVERLOAD : THREE PHASE THERMAL OVERLOAD (49)
- OVER VOLTAGE : THREE PHASE OVEROLTAGE (59)
- UNDER VOLTAGE : THREE PHASE UNDER VOLTAGE (27)
- Other protection systems as specified in the drawings.

(4) SCADA system requirements:

(a) Connect the command control signal cable of the 24 kV switchgear cubicle and Multifunction Protection Relay through the protocols network according to the IEC 61850 standard.

(b) The Contractor shall use SCADA in accordance with transmission protocols network IEC 60870.

(c) Able to display various status values including monitoring operation of the newly installed medium voltage switchgear cabinet via SCADA system.

(d) Provide computers and monitors at the control building to be able to provide mimic color, the change of symbolic color of various equipment and lines of busbar incoming line and outgoing line from MVS cabinet at every point when there is a change in the status of equipment and electrical system.

(e) To display status, alarm and record as shown in the drawings.

(f) Able to show the direction of current flow through the medium voltage switchgear cubicle at both incoming and outgoing at the computer screen.

(g) Able to remote monitor various values of Protecting Relay devices installed with medium voltage switchgear as specified in the form from the mobile phone system through the network of the SCADA system.

S6.10.4 FACTORY TEST

a. Visual Inspection and Dimensions Check
b. Mechanical Check
c. CT and PT Function Test
d. Circuit Breaker, Relay and Metering Function Test
e. Dielectric Test

S6.10.5 SITE TEST

a. Visual Inspection
b. Mechanical Check
c. CT and PT Function Test
d. Check low resistance main contact of circuit breaker
e. Circuit Breaker, Relay and Metering Function Test

S6.11 LOW VOLTAGE SWITCHGEAR, MDB and LV PANELS

S6.11.1 GENERAL REQUIREMENT

Low voltage switchgear shall be designed for receive electric power from generator, supply electric power to auxiliary load, and export power to PEA's 22kV distribution system via step-up power transformer. Low voltage switchgear shall consist of 2 sets of air circuit breaker (ACB) for generators, 1 sets of molded case circuit breaker (MCCB) for incoming feeder of main distribution panel, 2 set of MCCB for tie feeder, 1 set of MCCB for 100kVA emergency diesel generator and 1 lots of MCCB for outgoing feeder to supply auxiliary loads.

ACB shall be local controlled (close/open) at switchgear and remote controlled via the plant control system located in control room.

ACB for power source no.1 and power source no.2 shall be provided with mechanical or electrical interlocking and shunt trip device. Both incoming's ACBs shall not be closed at the same time.

MCCB for tie feeder and EDG feeder shall be provided with mechanical or electrical interlocking and shunt trip device. Both MCCBs shall not be closed at the same time.

S6.11.2 LOW VOLTAGE SWITCHGEAR

(1) Main Powerhouse
   a. Applicable standard: IEC standard
   b. Type of enclosure: Metal enclosed switchgear
   c. Rated voltage: 3,600V
   d. Service voltage: 3,300 V, 3 phase, 4 wire
   e. Frequency: 50 Hz
   f. Rated short-time withstand current (Isc) at 1 second: shall be verified by short circuit calculation and the selected rating shall be higher than the result of calculation.
   g. Rated peak withstand current: not less than 2.3 Isc as per IEC standard
   h. Power frequency test voltage: shall comply with IEC standard
   i. Auxiliary power supply: 125 Vdc
   j. Space heater shall be provided for anti-condensation
   k. Form of separation: 3b
   l. Air circuit breaker (ACB) : 630A, withdrawable type, shunt trip circuit, motor operated stored energy closing mechanism
   m. Protection unit attached in ACB: Integral, electronic-type trip, selt-contained current sensors, 3 phase over current and ground fault with inverse time & instantaneous characteristics
   n. Grounding System: TN-S as per IEC standard
   o. Indication on each feeder: breaker status, protection, metering, alarm and trip, lamp test, local/remote selector switches with key-operated
   p. Special tools and Software shall be provided for installation, lifting, transport, configuration setting, upload/download program, maintenance,
   q. Individual protective relay shall be provided for generator protection and for interconnection with PEA as required in PEA Grid Code.

(2) Emergency Channel
   a. Applicable standard: IEC standard
   b. Type of enclosure: Metal enclosed switchgear
   c. Rated voltage: 660V
   d. Service voltage: 400 V, 3 phase, 4 wire
   e. Frequency: 50 Hz
   f. Rated short-time withstand current (Isc) at 1 second: shall be verified by short circuit calculation and the selected rating shall be higher than the result of calculation.
   g. Rated peak withstand current: not less than 2.3 Isc as per IEC standard
   h. Power frequency test voltage: shall comply with IEC standard
   i. Auxiliary power supply: 125 Vdc
   j. Space heater shall be provided for anti-condensation
   k. Form of separation: 3b
   l. Molded case circuit breaker (MCCB) with motor drive : 400AT, 50 kA
   m. Protection unit attached in MCCB: Integral, electronic-type trip, selt-contained current sensors, 3 phase over current and ground fault with inverse time & instantaneous characteristics
   n. Grounding System: TN-S as per IEC standard
   o. Indication on each feeder: breaker status, protection, metering, alarm and trip, lamp test, local/remote selector switches with key-operated
   p. Special tools and Software shall be provided for installation, lifting, transport, configuration setting, upload/download program, maintenance,
   q. Individual protective relay shall be provided for generator protection and for interconnection with PEA as required in PEA Grid Code.

S6.11.3 MAIN DISTRIBUTION BOARD

a. Applicable standard: IEC standard
b. Type of enclosure: Metal enclosed
c. Rated voltage: 660V
d. Service voltage: 400/230 V, 3 phase, 4 wire
e. Frequency: 50 Hz
f. Rated short-time withstand current (Isc) at 1 second: shall be verified by short circuit calculation and the selected rating shall be higher than the result of calculation.
g. Rated peak withstand current: not less than 2.3 Isc as per IEC standard
h. Power frequency test voltage: shall comply with IEC standard
i. Auxiliary power supply: 125 Vdc
j. Space heater shall be provided for anti-condensation
k. Form of separation: 3b
l. MCCB circuit breaker: withdrawable type, shunt trip circuit, Motor drive operated with quick-make, quick-break, trip-free mechanisms of the toggle type
m. Protection unit attached in MCCB: Integral, electronic-type trip, short circuit, overload, ground fault with inverse time & instantaneous characteristics
n. Grounding System: TN-S
o. Indication on each feeder: breaker status, protection, metering, alarm and trip, lamp test, local/remote selector switches with key-operated
p. Special tools and Software shall be provided for installation, lifting, transport, configuration setting, upload/download program, maintenance,

S6.11.4 AC AND DC DISTRIBUTION BOARDS

a. Applicable standard: IEC standard
b. Type of enclosure: Metal enclosed
c. Rated voltage: 660V
d. Service voltage: 400/230 V, 3 phase, 4 wire
e. Frequency: 50 Hz
f. Rated short-time withstand current (Isc) at 1 second: shall be verified by short circuit calculation and the selected rating shall be higher than the result of calculation.
g. Rated peak withstand current: not less than 2.3 Isc as per IEC standard
h. Power frequency test voltage: shall comply with IEC standard
i. MCCB circuit breaker: trip circuit shall consist of overload protection and short circuit protection
j. Spare feeder: 20%
k. Grounding System: TN-S

S6.11.5 FACTORY TEST

a. Visual Inspection and Dimensions Check
b. Mechanical Check
c. CT and PT Function Test
d. Circuit Breaker, Relay and Metering Function Test
e. Dielectric Test

S6.11.6 SITE TEST

a. Visual Inspection
b. Mechanical Check
c. CT and PT Function Test
d. Check low resistance main contact of circuit breaker
e. Circuit Breaker, Relay and Metering Function Test

S6.12 MOTORS

S6.12.1 GENERAL REQUIREMENT

The Contractor shall be responsible to design, installation and testing all motors for support the operation of small hydro-power plant. Motors shall be 380V, 50 Hz for three phase induction motor and 220V, 50 Hz for single phase motor. Motor’s nameplate rating shall be greater than driven equipment at least 10 %.

S6.12.2 TECHNICAL REQUIREMENT

a. Rated voltage: 380V for 3 phase and 220V for 1 phase
b. Type: Induction motor, squirrel case rotor
c. Lock rotor current: 6-8 In
d. Power factor: not less than 0.85
e. Efficiency class: IE1-IE2
f. Insulation class: F
g. Temperature rise: class B
h. Starting method: Direct on line

S6.12.3 FACTORY TEST

a. Visual Inspection and Dimensions Check
b. Mechanical Check
c. Measurement of no-load current
d. Measurement of allow calculation of locked rotor current
e. Measurement of winding resistance
f. Overspeed test
g. High voltage test plus insulation resistance immediately
h. Inspection of bearings and mechanical operation of motor at no-load
i. Measurement of slip at full load
j. Vibration
k. Noise measurement
l. Starting time

S6.12.4 SITE TEST

a. Visual Inspection and Dimensions Check
b. Shaft Alignment
c. Running test of bearing
d. Measurement of insulation resistance

S6.13 BATTERY AND BATTERY CHARGER

S6.13.1 GENERAL REQUIREMENT

Batteries and battery charger shall be designed for normal DC loads and essential DC loads. Battery bank shall be capable of suppling all DC loads for two hours in case that battery charger is out of service or loss of main AC power supply.

S6.13.2 TECHNICAL REQUIREMENT

a. Applicable standard: IEC or IEEE
b. System voltage: 125 VDC, 2 wire
c. Battery charger capacity: supply 100% DC load and charging batteries at the same time.
d. Battery charger type: Industrial grade, application for small power plant
e. Battery charger output voltage: 125 VDC float charge
f. Battery charger input voltage range: ±10%
g. Battery charger output voltage regulation: ±0.5%
h. Function: alarm, indication and others as per manufacturer standard
i. Sound level: not more than 65 dBA
j. Battery charger protection device: ground fault protection
k. Battery type: Seal lead acid type
l. Battery capacity: shall be capable to supply 100% DC load and 100% UPS load for 2 hours in case of loss of main AC power supply
m. Battery design temperature: 25^{o}C
n. Battery Aging factor: 1.25
o. Battery volt per cell: 2 volts
p. Battery bank enclosure: metal enclosed cubicle located in control room
q. Battery’s protection & switching equipment: disconnecting switch and fuse

r. Special tool for lifting: Battery operated hand stacker
s. Battery and battery charger system shall be design as shown in drawing no. MML-PH-002 “LV single line diagram (AC, DC and UPS)”

S6.13.3 FACTORY TEST

a. Visual Inspection and Dimensions Check
b. Function Check

S6.13.4 SITE TEST

a. Visual Inspection
b. Electrolyte level check for each battery cell
c. Connection and wiring check
d. Electrical protection check for battery and battery charger
e. Voltage level check
f. Function check for battery charger

S6.14 UPS SYSTEM

S6.14.1 GENERAL REQUIREMENT

UPS system shall be designed for motor drive of main device switch, communication system, and other equipment safety and personnel safety.

S6.14.2 TECHNICAL REQUIREMENT

a. Applicable standard: IEC or IEEE
b. System voltage: 220 VAC. 1 phase, 2 wire
c. Inverter capacity: supply 100% essential load
d. Inverter type: Industrial grade, application for small power plant
e. UPS output voltage range: ±5%
f. UPS output voltage regulation: ±1.0%
g. Function: alarm, indication and others as per manufacturer standard
h. UPS system shall be design as shown in drawing no. THN-EM-02 “Single line diagram sheet 2/2”

S6.14.3 FACTORY TEST

a. Visual Inspection and Dimensions check
b. Function check
c. Alarm signal test
d. Inverter operation check
e. Static transfer switch check
f. Manual bypass switch check

S6.14.4 SITE TEST

a. Visual Inspection Function check
b. Alarm signal test
c. Inverter operation check
d. Static transfer switch check

e. Manual bypass switch check
f. Test for isolation transformer and voltage regulator for alternate source

S6.15 CABLES AND RACEWAY

S6.15.1 GENERAL REQUIREMENT

The Contractor shall design cable and conduit schedules, cable interconnection wiring diagrams and cable routing 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 complete cable tray, cable trenches, closed conduit system and supports, for all cable and conduit schedules, cable/raceway sizing study, and termination/connection wiring diagrams shall be designed and submitted by Contractor. All cable raceway shall be designed to ensure suitable drainage.

S6.15.2 TECHNICAL REQUIREMENT FOR MV POWER CABLE

a. Size as calculation required (except 22kV cable that connected to PEA shall be refer to Short circuit capability on PEA grid code)
b. Conductor material: Stranded copper
c. Insulation: XLPE
d. Cables shall have a rodent protection by mean of brass tape or steel wires armor underneath the outer jacket.
e. Suitable cross section of power cable shall be based on load and short circuit carrying capacity calculation, however current carrying capacity of power cable will be determined by using the reduction factors from IEC 60287 Standard and approved by Engineering team.

S6.15.3 TECHNICAL REQUIREMENT FOR OTHER CABLES

a. LV power cables shall be 0.6/1 kV, multi or single-core, XLPE insulation, FR-PVC outer jacket, 90^{o}C temperature rating.
b. Control cable for control, relaying and metering shall be 600/1000V class insulation, multi-conductor, stranded copper, XLPE or PVC insulated, FR-PVC oversheath.
c. Instrument cable to avoid induced currents and voltages shall be 600V class insulation, PVC insulated, FR-PVC oversheath. Single and multiple pairs shall have an overall shield. Multiple pairs shall also have each pair shielded.
d. Annunciation and instrument transformer secondary wiring shall be 600/1000 volts multi-core, FR-PVC outer jacket, 75°C temperature rating.
e. Cable for fire detectors shall be PVC insulated and fire resistant cable.

S6.15.4 TECHNICAL REQUIREMENT FOR RACEWAY

a. Cable tray and racks: Cable trays and racks shall be made of galvanized steel of suitable size approved by the Engineer. Cable tray covers shall be provided for the top most layer and outdoor area tray. All steel fittings, rods, nuts and bolts shall be hot-dip galvanized except where technically not possible,

b. Cable supports: Hot dipped galvanized 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.
c. Conduit system: Rigid Metal Conduits and Fittings Rigid metal conduits and all fittings shall be seamless, hot-dip galvanized steel meeting the IEC Standards and used in all area especially where there is danger of mechanical damage. Non-Metallic Conduit and Fittings shall be used in all cases, except in areas where there is danger of mechanical damage and conform the IEC 60614-2-2 Standards. Flexible Steel Conduit shall be used in general only for small runs near the equipment where rigid conduit cannot be used conveniently as approved by the Engineer.
d. Cable trench: The cable trench shall be of cast in-situ, prefabricated concrete slabs or of concrete block construction with concrete or steel covers. Where cable trench crosses under roads, railroads, or heavy equipment areas and where drainage facilities are required, special provisions shall be made. Trench drainage and drywell systems shall be provided.

S6.15.5 FACTORY TEST

The insulated power cables shall be completely constructed and fabricated in the factory and subject to tests in accordance with the relevant IEC Standards.

S6.15.6 SITE TEST

The power cables shall be tested after installation according to IEC 60230 and IEC 60811 Standards.

S6.16 COMMUNICATION SYSTEM

S6.16.1 GENERAL REQUIREMENT

Communication system shall consist of telephone system and local area network (LAN) for small hydro-power plant. All equipment shall be designed, manufactured, tested and installation in accordance with IEC, NEC or EIT standards.

S6.16.2 TECHNICAL REQUIREMENT FOR TELEPHONE SYSTEM

Telephone PABX system and Analogue telephone set shall be provided. Telephone set shall be generally of desk type mounting and line cord terminated at the jack station unless otherwise not possible, wall type may be considered.

S6.16.3 TECHNICAL REQUIREMENT FOR LAN SYSTEM

a. The Contractor shall furnish and install LAN equipment including switching hubs, 8 pin LAN jack, two (2) wireless LAN Dual radio (IEEE 802 11a/b/g) PoE access points, cabling, boxes, and all auxiliaries connection equipment at electrical and control room.
b. LAN shall be redundant system. Failure of any component shall not interrupt the operation of the system other connecting system.

c. Switching hubs of shall be of auto-sensing 10/100/1000 Base-TX 24 ports (RJ-45 type) with 2 ports single mode fiber optic Gigabit type Ethernet (1000 Base Lx)

S6.16.4 FACTORY TEST

Test report for telephone and LAN system shall be provided as per manufacturer standard and comply with IEC/IEEE standard

S6.16.5 SITE TEST

a. Visual check
b. Connection check
c. Functional check
d. Other check shall be performed as per IEC/IEEE standard

S6.17 CCTV SYSTEM

S6.17.1 GENERAL REQUIREMENT

The cameras shall be furnished and installed for the inside/outside plant's area to give the operator the visual monitoring in the control room. CCTV system (Closed-Circuit Television System) shall be interfaced and controllable from control room.

S6.17.2 TECHNICAL REQUIREMENT

a. The cameras shall be IP CCTV type, minimum degree of protection for equipment
b. IP fixed indoor type: IP41
c. IP PTZ outdoor type IP54
d. IP fixed camera indoor type shall be located on the major equipment
e. IP PTZ camera shall be installed at turbine area including entrances, security areas and for transformer area, switchyard, and spillway IP PTZ shall be installed on the poles.
f. The monitor shall be installed at control room. Monitor shall be the high-resolution monitor and flicker free, long hours of viewing without inducing visual discomfort.
g. All channels may be recorded continuously, even when their view is not being displayed to the operator, so that missed views can be reviewed later from the video recording.
h. Video recording period of CCTV system shall not be less that 30 Days

S6.17.3 FACTORY TEST

Test report for CCTV equipment and material shall be provided as per manufacturer standard and comply with IEC/IEEE standard.

S6.17.4 SITE TEST

a. Visual check
b. Connection check
c. Functional check
d. Other check shall be performed as per IEC/IEEE standard

S6.18 FIRE DETECTION AND ALARM SYSTEM

S6.18.1 GENERAL REQUIREMENT

The Contractor shall design, manufacture, shop test, supply, installation and commissioning for detection systems. All equipment and works under this Specification shall comply with the requirements of the Thai Industrial Standard, National Electrical Code, The Engineering Institute of Thailand, and National Fire Protection Association (NFPA) standard. Main fire control panel, detection systems, including manual alarm station (manual pull stations), alarms bell, controls, wiring, conduit, fire detection devices, and instrumentation shall be furnished.

S6.18.2 TECHNICAL REQUIREMENT

a. Smoke Detector: 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 and spacing shall be in accordance with NFPA 72 and the manufacturer's guidelines. Smoke detectors shall be the photo electric type.
b. Manual Alarm Station: Manual alarm station shall be for sending a fire alarm signal to the control panel by operating the push button. 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.
c. Supervisory Control Panels: Each supervisory control panel shall continuously monitor its associated fire detection or suppression system (or systems).
d. Control Panel 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.
e. Backup Battery: Fire alarm bells and trouble alarm horns shall be NEMA 12 rated. Fire alarm bells and trouble alarm horns shall be located at supervisory control panel. A fire alarm bell shall be sounded when any system actuated, The minimum sound output for each fire alarm bell shall be 85 dB at 3 meters (10 feet) from the device. 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.
f. Alarm and Test Devices: The circuit for this switch shall permit audible annunciation of additional incoming alarms. Lamp test and reset push buttons shall be provided.

S6.18.3 FACTORY TEST

According to National Fire Protection Association (NFPA) Standards

S6.18.4 SITE TEST

a. Visual check
b. Connection check
c. Functional check
d. Other check shall be performed as per National Fire Protection Association (NFPA) Standards

S6.19 PLC SYSTEM

S6.19.1 GENERAL REQUIREMENT

Programmable Logic Controllers (PLC), microprocessor-based control system, shall be applied for control tasks referring to the drawing no. MNN-EM-04. They shall be provided as complete, operable systems, including all accessories necessary for erection, commissioning, operation and maintenance. The equipment and system shall be the latest available offering of both software and hardware at the time of the system manufacture. The manufacturer shall have sales and services representatives located in Thailand.

S6.19.2 TECHNICAL REQUIREMENT

(1) Programmable Logic Controller (PLC)

PLC shall be designed and conformed to IEC 61131. The PLC equipment shall be designed in accordance with IEC 60801 - Electromagnetic Compatibility for Industrial-process Measurement and Control Equipment. PLC shall be designed based on a redundant architecture including redundant processors, redundant power supply and redundant communication equipment. Software shall be based on MS Window plate form.

The PLCs shall consist of central processors, input/output, interfaces modules, memory, and power supplies. Data highway and high speed data network connecting the workstations shall be provided.

PLC control system shall be time synchronized with the GPS Master Clock via IRIG-B or Ethernet port.

PLC control system shall be provided with two (2) operator workstations for remote operation, one (1) SOE server and one (1) engineering station (laptop). Full version with license of all required software including operating system, programming software, HMI software and etc. shall be provided.

- Central Processing Unit (CPU)
  CPU shall be 32 bit processor as minimum. Hot standby redundant controllers shall be designed for a bumpless transfer of control from the active controller to the standby controller.

  The CPUs shall not be loaded to over 60% of its available capacity.

- Memory Unit
  The memory shall be EEPROM or FLASH memories. The capacity shall be capable of retaining configuration information at least 1 year.

- Input/Output modules
  Number of input / output points per card shall not exceed 16 (six teen) for digital and 8 (eight) for analog / thermocouple / RTD signals.

  The spare channel (10% as minimum) shall be fully wired and terminated.

(2) Operator Workstation (OWS)/SOE server

Two (2) operator workstation computers and one (1) SOE server shall be provided and installed in the control room. Each computer shall be workstation class including 24 inches color LCD monitor (16:9 ratio), electronics, keyboard and optical mouse. The computer specification shall meet the minimum requirements as follows:

Processor:	Intel Xeon Bronze Processor 1.9GHz, 6C
Memory:	16GB DDR4 RDIMM EEC
Hard disk:	2x500GB SATA 7200RPM RAID 1 configuration
Graphic card:	MID Range 3D graphic card with DVI/DP interface
Monitor:	24 inch WLED 1920x1200 with adjustable stand

(3) Engineering Workstation (EWS)

One (1) engineering workstation computer shall be provided for engineering tool which uses to configure, program and maintenance of PLC control system. EWS computer shall be shall be workstation class (laptop type). The computer specification shall meet the minimum requirements as follows:

Processor:	Intel Core i7 Processor 2.6GHz, 6C
Memory:	16GB DDR4
Hard disk:	1TB SATA 7200RPM
Graphic card:	MID Range 3D graphic card
Monitor:	15.6 inch display

(4) Printer

One (1) A3 color laser printer shall be provided and interfaced to network (Ethernet). The printer resolution is at least 600 x 600 dpi with automatic duplex printing function. The printer with printer desk shall be installed in a control room.

(5) Network switch

Redundant industrial grade layer2/layer3 Ethernet switches shall be provided.

(6) Master clock system

The contractor shall furnish all required master clock system including GPS antenna, synchronized time code generator, lightning arrester, cables and all accessories. All control systems shall be connected to the master clock system. The master clock system shall be a GPS based system which receive time signals from satellite signal. Interfacing with the control systems shall be IRIG-B or NTP. Outdoor antenna, lighting protection, power supply shall be supplied. One set of digital clock indicator (5 inches digit size as minimum) shall be provided and located in the control room.

(7) Control cabinet/Marshalling cabinet

All cabinets shall be of modular design, complete with all accessories, assembled and wired at the factory ready for installation, external connections and service. The cabinets shall be located in control room with air condition.

The cabinet shall be made of steel sheet with aluminum frame. The cabinet dimension shall be 800 cm. in width, 600 cm. in depth and 2,100 in height. The base frame and supporting structures shall be anchored to the floor (raised floor control room). Front and rear doors shall be provided so that the maintenance will be easily accessible.

The cabinet degree of protection shall be IP 42 as minimum. The cable entry shall be at the bottom only. The cable grommets and cable clamps shall be provided for protecting cables.

(8) Control console

The control console shall be designed in accordance with Human Factors of Design and ergonomic standards. The control console shall have workspace for at least three (3) computer stations, communication and operator interface device. Each control console shall consist of processor shelves, ventilation Fan, circuit breaker, receptacle, cable raceway, etc.

The Contractor shall provide three (3) high back adjustable five wheels chairs with arm rests in the control room.

S6.19.3 FACTORY TEST

a. According to Manufacturer's Standards.
b. PLC hardware visual and functional test.
c. PLC software functional test.

S6.19.4 SITE TEST

a. According to Manufacturer's Standards.
b. I/O loop check.
c. PLC control system function test.

S6.20 SCADA SYSTEM

S6.20.1 GENERAL REQUIREMENT

SCADA systems shall be able to interface, monitor and distribute signals in various systems as follows:

(1) Gas insulated medium voltage switchgear (24 kV insulated switchgear)
(2) Generator cooling system
(3) Generators
(4) Transformers
(5) Low voltage switchgear
(6) LAN networking
(7) CCTV system
(8) Fire detection and notification system
(9) Wireless internet system
(10) Other systems that are defined in the contract drawing

S6.20.2 TECHNICAL REQUIREMENT

(1) SCADA System Level

Ethernet connections established through backbone Mobile network Link to RTU located in each location using IEC-60870-5- 104 protocol, TCP/IP connection. Similarly, the SCADA system at Network level shall transmit/receive data from PLC system through backbone transmission network using IEC-60870-5- 104 protocol, TCP/IP connection.

(2) SCADA RTU Level

In the SCADA RTU level, RTU System is available to monitor all the sub-systems at its respective station and other location. The RTU system receive/send data from/to the Sub-systems via TCP/IP connection using IEC61850 Standard and Modbus TCP protocol and Modbus RTU protocol via serial communication. The acquired data is then sent to the Network level SCADA servers via DTS network through TCP/IP connection using IEC-60870-5- 104 protocol.

(3) System Design Description

Generally, the SCADA system consists of the following main components:

- SCADA Server
- Operator Workstation
- Ethernet Switch
- Peripherals device
- Remote Terminal Unit (RTU)

1. SCADA Server

The SCADA servers are high-profile pre-tested Dell computers running under the Windows operating system in the MicroSCADA application software. The mode of communication between the workstations and the real-time SCADA Servers is accomplished using TCP/IP network services. This system responsible for acquiring data from and sending commands to the stations. All monitoring and control functions related to line wide operation are controlled and managed at this level.

2. Operator Workstation

The Operator Workstation is based on the Microsoft Windows Operating System that provides a rich range of Graphical Development tools and each workstations with three monitors.

All Workstations are identical in their ability to perform control and monitoring functions. Access control is dependent on user configuration and independent of location or specific Workstations.

Workstations are always connected to the Hot-SCADA server. When the current Hot-SCADA server failure and the standby server become hot stage , the workstations shall switch the connection to the current Hot-SCADA server. Due to the resilience design of the databases, this ensures consistent and synchronized data during switchover.

The core design aspect of the Operator Workstation through which control room operators interact with the SCADA system are graphical, user friendly, ergonomic, consistent, uniform and economicalin number of steps needed to present the requested information, or to effect a command action. Through the use of the Operator Workstation, real-time status monitoring and control of various remote field equipment can be achieved.

All information and details presented on the workstations are displayed in a clear manner. Information presented adopts a color scheme philosophy, which is consistent for the symbols and displays.

3. Ethernet Switch

Simulation Workstations and Laptop for SCADA and other software configuration are connected to the Ethernet switch . The Ethernet switch is then connected to DTS Network where RTU System and oth er Sub-systems of Yellow line Stations are connected.

Physically the Ethernet bus is realized by single or multiple Ethernet switches, allowing point-to-point communication to all nodes.

The SCADA Server network shall use the RSTP configuration. RSTP mechanism keeps communication ring open to avoid circulating packages . I n case of a fault in the communication ring, the virtual interruption is Closed . This re-configuration of the network requires time of 5ms.

4. Peripherals device

Printers shall be provided for recording alarms, operator transactions and system reports.

The following peripherals device are provided follow contract drawing.

5. Remote Terminal Unit (RTU)

Remote Terminal Unit (RTU) c onsist of redundant power supply, redundant central processing, and redundant communication paths based on IEC 60870-5- 104 for controlling the interfaces connected to the SCADA system. Degrees of robustness are built into the design as the RTU are based on a redundant and hot- standby configuration as such to handle any single point of failure.

Remote Terminal Unit Specification

Type	:	Floor mounted standalone panel
Dimension	:	2200H x 800W x 800W,
Shell protection	:	IP 43
Panel color code	:	RAL7035.
Door opening	:	Both front and rear opening.
Front Door type	:	Front opening (swing frame with RTU mounting) with additional glass door.
Rear Door type	:	Rear single door without additional glass door.

Note: The RTU s hall be installed on swing frame on front of RTU panel. The rear side panel s hall be considered as marshalling panel for RTU.

S6.20.3 TRAINING

(1) The contractor has to train the staff of DEDE at least 2 times, the number of participants is not less than 10 persons.

(2) The contractor shall submit a training agenda, training schedule and the qualifications of the speakers to the employer for approval at least 15 days before the training.

(3) The contractor shall prepare a training manual consisting of user manual, maintenance manual, command/write/set program details and reference documents to deliver to the employer at least 10 sets.

(4) The topics in the SCADA training must not be less than the following:
- System overview
- User interface
- Field controller communication with the operation
- Configuration environment
- Operator environment
- Event and alarm handing
- Display design
- Historical, trend/bar chart and report
- Database communication

(5) All costs of training and equipment shall be borne by the contractor.

S6.21 TRANSFORMER

S6.21.1 SCOPE OF WORK

The work to be done under this section consists of the design, manufacture, testing, delivery to site, installation, ISO standard, TIS standard, PEA standard, placing in successful service and guarantee of

Two (2) set of outdoor transformers of minimum capacity at 1,700 kVA.
Two (2) set of outdoor transformers of minimum capacity at 700 kVA.

S6.21.2 PURPOSE AND FUNCTION

The transformer will step up the generator voltage from 3.3 kV and 0.4 kV (nominal) to the transmission line voltage of 22 kV (nominal). Transformer will transfer power from a generator, rated for 1,400 kVA and 2 x 280 kVA, 3-phase and 50 Hz.

S6.21.3 STANDARDS

The transformer shall be manufactured and tested in accordance with the latest TIS 384, JEC 204, VDE and DIN, or equivalent; unless otherwise specified in these specification HV and LV bushing shall be in accordance with the latest DIN 42531 and DIN 42530 respective, or equivalent; unless otherwise specification.

S6.21.4 TYPE OF TRANSFORMER

The transformer shall be 3-phase, 50 Hz, two windings, outdoor type OA (oil-immersed, natural air cooled circulation), and Hermetically Sealed corrugated tank (or) Conservator Tank with self-standing on concrete platform.

S6.21.5 MEGAVOLT AMPERE RATING

The continuous rating shall be based on an average copper temperature rise of 60ºC and hottest spot of 75ºC over an ambient maximum temperature of 45ºC. Thermally upgraded paper shall be used.

S6.21.6 VOLTAGE RATINGS, CONNECTIONS AND TAPS

The high voltage winding shall beconnected for operation at 22 kV, line-to-line, and shall be equipped with 4 full capacity, off-load taps at ± 2.5 percent, ± 5.0 percent based on 22 kV.

All voltages are based on the turn ratio of the transformer at no load.

The high and low voltage winding shall be connected according to Provincial Electricity Authority (PEA)'s regulation.

S 6.21.7 INSULATION LEVELS

The Insulation level of HV windings and connected parts of transformers shell be as follows:-

Nominal System Voltage (kV, rms)	Insulation	
	Impulse Test Voltage Full-wave (kV, peak)	Power Frequency Test Voltage, 1-min (kV, rms)
22	125	50

S6.21.8 IMPEDANCE AND LOSSES

The percentage impedance shall be 6.0 percent at 75ºC, based on and rated voltage. No-load losses and load losses shall be according to PEA standard.

S6.21.9 SHORT CIRCUIT CAPABILITY

When connected for normal, full-load operation, the transformers shall be capable of withstanding, without injury, a 3-phase short circuit on the terminal of any winding for duration of 2 seconds. It shall be assumed that rated voltage shall be maintained behind the reactance of system and generators.

S6.21.10 SOUND LEVEL

The transformer shall be designed to operate without exceeding the average sound levels prescribed by NEMA TR 1.

S6.21.11 HIGH FREQUENCY INTERFERENCE

The transformer shall be designed to operate without causing interference directly or indirectly to television reception and telephone communication circuits, and shall not cause radio interference in excess of the suggested tolerance limits of NEMA TR 1.

S6.21.12 BUSHINGS AND CONNECTORS

The transformer shall have the high voltage and low voltage leads brought out from the tank through bushings best suited for the voltage of the winding and with a high factor of safety. Outdoor bushings shall be in accordance with ANSI C76.1 and shall be rated as follows:-

Bushing	Impulse Full-wave (kV, peak)	Low-Frequency (kV, rms)	
		Dry 1-min	Wet 10-sec
HV. Bushing for 22 kV system	125	50	50
LV. Bushing	30	10	10

All bushings shall be provided with threaded bushing studs and connectors.

Suitable connectors for bus, etc., shall be supplied, with all bushings, subject to the PEA approval.

Neutral bushings will be connected to a copper bus or copper conductor. There shall be no connection of the neutral lead to the inside of the tank.

Bushing arrangements, stud dimensions and connectors shall be subject to the approval of the PEA.

All bushings shall be designed to eliminate harmful stressing of any parts due to temperature changes and to provide for conductor expansion. All porcelain used in the bushings shall be homogeneous, free from laminations, cavities or dielectric quality. The glazing shall be uniform in color and free from blisters, burns and other defects. All porcelain parts shall be one piece, well vitrified, tough and impervious to moisture.

S6.21.13 OFF-LOAD TAP CHANGER

The transformer shall be equipped with a full megavolt ampere capacity off-load tap switch. The top changer shall include operating wheel or handle, indicating pointer and dial, and means for locking in any desired position. The locking device shall be arranged to prevent locking the tap switch in an intermediate position. The tap switch position indicator shall be visible form ground level while operating the tap switch. The tap switch shall provide 4 full capacity 2-1/2 percent voltage adjusting steps-2 above and 2 below the 22 kV.

The complete tap changing mechanism shall be built to meet all operating conditions and shall have high electrical, mechanical and thermal safety factors to withstand the full short circuit current of the transformer without damage. The switch contacts shall be silver- plated.

S6.21.14 CONSTRUCTION

The core shall be manufactured of high-grade, grain-oriented, non-aging sheet steel laminations having smooth surfaces. The core steel and all insulation associated with the core shall be designed so that no detrimental changes in physical or electrical properties will occur during the life of the windings.

The laminations of core type transformers shall be glass tape wrapped or bolted. Core bolt insulation shall be suitable for 130ºC (Class B) minimum.

The core stack shall be grounded internally through grounding links located on top of the core to permit testing of the individual core packages for grounds.

The core steel and windings shall be suitably braced to prevent displacement or distortion during transportation and conditioned for permissible short circuit and overload. Suitable lifting attachments shall be provided for untanking the core and coils with a minimum of headroom. The design and location of lifting points shall be such as to preclude distortion of the core or damage to the core bolt insulation under lifting stresses. Lifting stress shall not be transferred between top and bottom clamps through the core iron.

All windings shall be copper. The winding insulation materials throughout shall be thermally upgraded and shall be 105ºC (Class A) or higher.

Non-brazed electrical connections shall be compression type, 2-bolt connectors.

All fabricated steel shall be free from distortion and constructed according to the approved Drawings.

All oil-filled compartments mounted on the side of the main tank shall have a 12 mm minimum raised lip to prevent dripping of oil with the covers removed.

To maintain oil tightness, gasketed joints shall be designed and constructed to ensure even and effective pressure without overstressing the gasket, even under conditions experienced during vacuum filling of the main tank. When installed in position, the outer edges shall be protected by metal-to-metal stops or fire-resistant stop gasket material.

A relief vent shall be mounted on the cover adjacent to and projected beyond the expansion tank, discharging at a level above it. A sealed diaphragm shall be installed in both the top and bottom of the vent. The vent shall be equipped with a screen to prevent fragments of ruptured diaphragm from entering the transformer. The vents shall have the highest point not less than the height of their conservators and shall be designed to have the vent outlets face towards the ground with this height approximately 50 cm above ground level in order to protect splash over of oil in case the pressure relief device is operated. The pressure relief vents shall be equipped with alarm contacts.

Two ground pads shall be fitted at diagonally opposite corners of the base. Each pad shall include a clamp type terminal and bolts suitable for a 95 mm^2 stranded cable. Bolt holes in the pads shall be 35 mm deep.

A ladder shall be located on the side of the transformer tank for climbing onto the transformer. It shall extend from the base of the transformer to a minimum of 0.50 m above the cover, with an adjacent handhold to assist in moving from ladder to cover. The lower part of the ladder shall be equipped with a barrier and locking device to prevent its use by unauthorized personnel.

S6.21.15 BASE

The base shall be designed to permit moving the assembled and oil-filled transformers on skid plates or rollers. Length and spacing of each pair of reinforced parallel rolling areas shall be such that the fully assembled transformers, with or without oil, can be safely tilted 15 deg. Internal reinforcing shall not prevent draining of all liquid from the tank.

The transformers shall be provided with fixed structural steel skids suitable for skidding or rolling the transformers in any direction. Eyes for attaching hauling equipment shall be supplied on each side of the transformer, so that the transformer may be hauled in all four directions relative to the transformer tank. Location of the eyes shall be approved by the Engineer.

S6.21.16 TRANSFORMER TANK OR CORRUGATED TANK

The transformer tank and assembled radiators, the conservator tank, shall be suitable for filling with oil in the field. The completely assembled transformer with oil shall withstand a pressure of 1.00 kg/cm^2 or 125 percent of maximum operating pressure measured at the elevation of the cores.

S6.21.17 CONSERVATOR TANK (If selected)

A conservator tank shall be mounted above the radiator bank. The tank shall have a minimum capacity of 10 percent of the oil volume of the transformer tank and cooling system and shall be suitable for operating under vacuum. It shall be equipped with dehydrating breather, accessible from grade level and designed to permit capping, a 50-mm valve with plug at the top of the tank, a sump and 25-mm drain valve at the lower end of the tank, and a manhole for inspection and cleaning. The connecting pipe to the main tank shall be 50 mm diameter minimum and shall project at least 25 mm inside the expansion tank. A brass gate valve of the rising stem type with a handle which clearly indicates the position of the valve gate shall also be provided.

S6.21.18 RADIATORS OR CORRUGATED TANK

The transformer shall be provided with a sufficient number of radiators to permit operation at the self-cooled ratings without exceeding the specified temperature rise.
Radiators shall be mounted on the transformer tank or corrugated tank

Radiator valves shall be provided on each radiator connection to the interconnecting pipe, so that any radiator may be removed for repairs without taking the transformer out of service. Not required for hermetically sealed type transformer.

Radiators shall be equipped with provisions for draining.

S6.21.19 CONTROL

Suitable terminal blocks with a minimum of 20 percent spare quantity shall be provided to accommodate all wiring and cables.

All conduit and wiring between each item of equipment and the main control cabinet shall be provided.

S6.21.20 OIL

A sufficient quantity of oil shall be supplied in drums with 10 percent extra to allow for spillage. The oil shall have a dielectric strength, when shipped, of are least 30 kV as measured in accordance with ANSI specifications. The oil shall be mineral oil complying with the latest ANSI standard on insulating oils. Three certified copies of test reports stating the dielectric strength of the oil shall be supplied to the Administration prior to energizing the transformer.

S6.21.21 ACCESSORIES

The transformers shall be furnished and equipped with the following accessories:

(1) HV and LV bushings, with terminal connectors.
(2) Bird guard cap (bushing cover), ultra-violet and track resistant material, e.g. Polypropylene, neoprene, etc; which is suitable for exposure to sunlight.
(3) Arcing horns, corrosion-proof, according to DIN 42531.
(4) Tap changer
(5) Thermometer pocket with contacts.
(6) Oil level gauge with contacts.
(7) Buchholz relay with contact.
(8) Pressure relief device with contact.
(9) Nameplate with connection diagram.
(10) Oil drain valve with plug or cup, installed at the lower part of the tank.
(11) Sludge drain plug, installed at the bottom of the tank.
(12) Earthing terminal, with solderless clamp type connector suitable for steel stranded conductor diameter of 9.0 mm (size 50 mm^2); complete with lock- washer of stainless steel or better.
(13) Lifting lugs.
(14) Lifting eyes on the cover
(15) Oil conservator with dehydrating breather and oil level gauge with contacts. The cylinder of dehydrating breather shall be of transparent glass. The dehydrating breather shall be easy replaced and filled with silica-gel not less than 1.0 kg. It is not required for hermetically sealed type transformer.

S6.21.22 TESTS

The transformers shall be test according to PEA standard. The testing costs are the costs of the contactor.

Routine test such as

(1) Resistance of high and low voltage windings on all taps.
(2) Exciting current and no-load loss on rated voltage connections at rated voltage and 110 percent of rated voltage (to be performed after impulse test).
(3) Impedance and load test at rated current on the rated voltage connection and on the tap extremes (1 transformer only for tap extremes).
(4) Polarity and phase relationship tests.
(5) Ratio of all taps.
(6) Control components and auxiliary wiring tests. Where applicable, tests shall be performed on each transformer in accordance with the relevant standard:
    - Dielectric.
    - Control wiring.
    - Mechanical.
(7) Applied and induced voltage tests.
(8) Temperature rise test.
(9) Mechanical tests, including pressure tests to establish the integrity of the tank and cooling system

S6.22 REQUIRED SPARE PART

S6.22.1 GENERATOR

The Contractor shall furnish the following parts for which unit prices shall be included in the List of Materials and Prices :

a. Stator winding: Five (5) top/bottom bars or coils
b. One (1) field coil (for one pole)
c. One (1) complete set of bearings (metal or ball/roller)
d. One (1) complete set of diodes bridge or thyristors bridge for excitation system
e. One (1) complete set of electronic printed cards of each type used in the excitation system.
f. One (1) resistance temperature detector for bearings of each type.
g. One (1) set of carbon brush and brush holder with accessories (if applicable)

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 Section