TECHNICAL SPECIFICATION

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1. Scope of Supply of Plant and Services

1.1 Background

Taelefaga hydro station has a present capacity of 4MW and is connected with a penstock to Afulilo dam with 10 million cubic meters capacity. Station has two 2MW generators each connected to twin jet Pelton turbines.

EPC is adding a new third 2MW generator that will increase station capacity to 6MW. A separate bid is currently being advertised to add this third generator.

Existing Unit No 2 generator is running well but it is Unit No 1 that often has problem with the alternator twin bearings that often fail after short period of running. Also aligning generator and turbine of this Unit No 1 is often difficult. This unit is again out of service at present for high vibration suspected to be caused by failure of the inboard main bearing of the generator. This same bearing was only replaced in 2016. EPC suspects the generator rotor shaft is slightly bent from when the plant was first commissioned in 1993.

EPC decides to change the generator or alternator of Unit No 1. Turbine, associated equipment, electro-mechanical controls, switchgear, transformer, etc. will not be changed.

This bid calls for supply and installation of a new generator of similar size to old one and must be compatible to the existing turbine; a twin jet Pelton Turbine.

1.2 Financing of Project

Project is funded by EPC from its local capital budget.

1.3 Existing Hydro Plant

The Taelefaga Hydro Station was commissioned in 1993 with two 2MW generators and a 10 million cubic meters Afulilo Dam. Plant was designed with provision to add a 3rd 2MW generator at a later time. Some of facilities for the 3rd 2MW generator are already built in place. This includes: inlet pipe from combine inlet manifold, generator/turbine concrete pad, tailrace, pad for the 6.6/22kv power transformer, and a spare 22kv circuit breaker to connect to the 3rd generator in the 22kv station electrical switchgear/busbar.

Taelefaga power station presently generates about 22 million kilowatt hour units per year, which is about 20% of Upolu Island annual energy demand. The 3rd 2MW generator will generate another 3.5 to 4 million kwh units from this plant annually.

1.2.1 Afulilo Dam

The Afulilo dam surface area is approximately 2.5km2 at full capacity of 10million cubic meters, with 1.8km 2 water surface at 90% capacity. The deepest point at the dam wall at crest level is approximately 11m. The dam surface elevation above sea level being 317.5m ASL (i.e. Spillway

level) and Penstock intake level at 306.5m ASL. Operating range of water in storage basin is 310m to 317.5m ASL. An aeration system built inside the dam was commissioned last year to mitigate formation of gas that has affected villages next to power station.

Figure 1 Afulilo Dam

1.2.2 Penstock

The penstock is a concrete lined and steel pipe. The 2,154m long pipe is comprised of 1.1m diameter steel pipe which branches out into three 400mm diameter pipes at the power station. Pipe is designed and sized to be able to supply adequate flow for three 2MW generators to run at full load. The pipe, with the turbine at full power provides a water flow of 1.85 cubic meters per second.

The pipe was repainted in 2010.

At first sight, the external part of the pipe and its supports seem to be in good condition. The concrete bases that support the pipe seem to be in good condition.

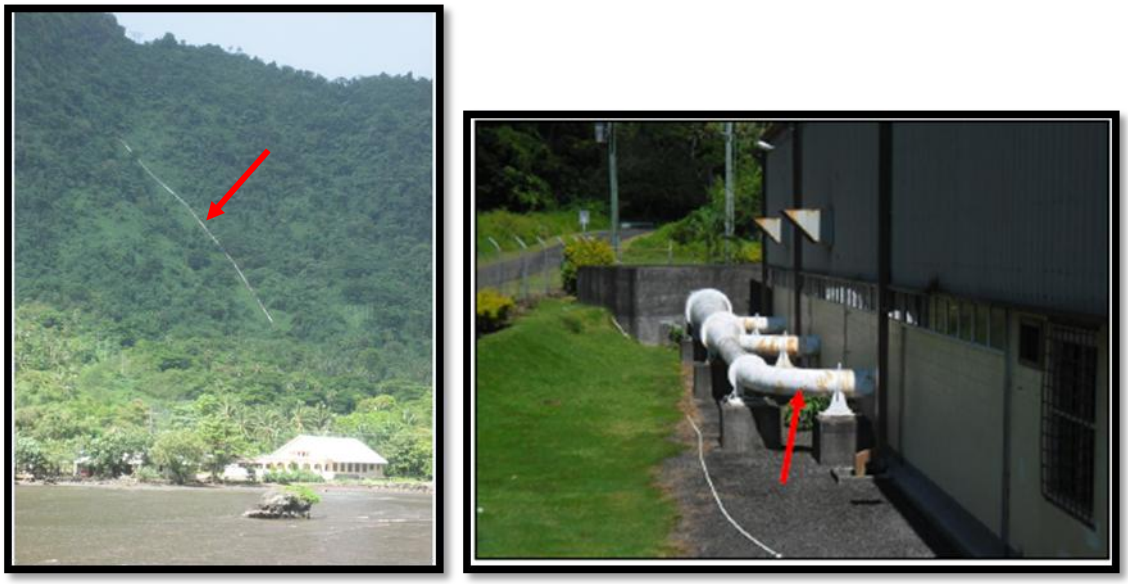

Figure 2: Taelefaga's penstock view from Fagaloa Bay and entrance into the power station with provisions for a third generator.

1.2.3 Tailrace and Stream

Water from power station after it generates electricity discharges to a 10 meter long open concrete tailraces into stream which takes water to sea, which is about 150 meters downstream from power station. Each of the 3 generators has its own 1.85 meter wide tailrace. With addition of a third generator, there will be an increase amount of water discharging from power station to tailrace and stream. It is part of the project to assess, widen, and reinforce stream banks on both sides of stream using rip rap rock wall to avoid erosion from increase flow. Also there is section of stream that needs widening to a minimum of 6 meters wide. Reinforcement of stream banks will involve building rip rap rock protection walls on both sides from where water discharge from tailrace to bridge.

1.2.4 Transmission Lines

Plant is connected to Island wide grid. Power is different distributed by the 22kv South Coast feeder and a 22kv tieline between this plant and the Lalomauga hydro plant. South Coast Feeder feeds power to Afulilo Dam, East part of Upolu to Aleipata and South side to Siumu village. From Lalomauga hydro station, a 33kv transmission and distribution tie transmits power to Tanugamanono power station from where power is distributed to 4 distribution feeders; Hospital feeder, Beach Road feeder, East Coast feeder, Afiamalu Cross Island feeder.

1.3 Scope of Work

1.3.1 General Description of Scope of Work

The Scope of Work is to replace the generator on Unit No 1 with a new 2MW/2.5MVA generator compatible to existing twin jet Pelton Turbine.

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Selected bidder is responsible for:

a) Assessment of existing No 1 Unit installation and equipment and controls.
b) Use information to prepare design and specification of a new generator and all associated equipment to connect to existing turbine and power output connected to existing switchgear and integrating with SCADA system for remote control (start, synch on line, control voltages, frequency, power factor, and real and reactive power output)
c) Place order of new generator and all required equipment and materials to complete installation after obtaining approval of design and specification of generator to be purchased.
d) Disassemble and remove old generator. This work shall be planned so that there is little time between removal of it and installation of new generator in order to shorten time that this machine is out of service.
e) Ship and transport generator and all equipment to the plant.
f) Prepare and submit to EPC for approval a Construction Environmental Management Plan (CEMP). Adhere to approved Plan.
g) Install new generator.
h) Conduct dry Commissioning of the generator, turbine etc.

i)

j) Conduct wet commissioning of generator

k) Conduct load testing and load rejection tests
l) Undertake Guarantee Tests
m) Handover of the Facility to the Employer on achievement of the requirements for Operational Acceptance
n) Provision of as built drawings
o) Provision of training for maintenance staff
p) Remedy defects notified during the Defect Liability Period
q) Warrant equipment and works for 12 months
r) Implement CEMP mitigation measures
s) Recommend and provide essential spare parts.

1.3.2 Key Performance Criteria

a) Generator capacity and operating efficiency and availability factors
b) Planning and scheduling of work to be performed during dry season so there is no loss of generation if dam spills as result of in availability of Generator No 1.
c) Complete installation and recommissioning of plant in shortest time possible.
d) Zero breaches of the CEMP mitigation measures
e) Safety of the public relation with communities along hydro facilities works sites

1.3.3 Design, Supply and Installation of new Generator

1.3.3.1 General

a) Supply a new synchronous generator compatible to design and operation characteristics of existing twin jet Pelton wheel turbine
b) Power rating of new generator to match power rating of existing Pelton turbine with 100% inlet gate open without exceeding its nameplate temperature rise rating.
c) Synchronous Generator, with the turbine runner supported on sleeve bearings mounted on an extended generator shaft.
d) Use existing twin jet Pelton Turbine, Spear valves, and deflectors fitted with hydraulic actuator(s).
e) Use existing lubricating oil pump and system.
f) Supply new generator complete with exciter and AVR.
g) Use existing 6.6kV switchgear for connection between new generator and existing 2.5MVA 6.6/22kv transformer.
h) Use existing Protective Relay scheme for new generator
i) Uses existing turbine-generator control panel with control system, indication SCADA Interface, generator protection (state of the art equipment), synchronizing interface, alarm system
j) Use existing battery and 110V DC system for control, alarm and protection purposes.

k) Use existing overspeed sensor for Emergency Butterfly valve for main penstock (re-calculate flow rate settings and set accordingly).

2. Specifications

2.1 Performance and Design

2.1.1 Guarantees

The Contractor shall provide the following guarantees:-

1. A generator minimum average efficiency guarantee as specified in Section 6 Part 2.42.4.32.4.3.2 for the new generator.
2. A control system Average System Availability guarantee as specified in Section 6 Part2.42.4.72.4.7.12.4.7.3.2.

The Employer may reject the Equipment if it fails to achieve the relevant guarantee.

2.1.2 Statutory Requirements

2.1.2.1 Background to Environmental

The Project has been the subject of an Initial Environmental Examination (IEE), which included an Environmental Management Plan (EMP) for the projects. The full IEE is included in Section 6 Part 4 - Supplementary Information.

The relevant Environmental Impacts and Mitigation Measures are detailed in the following Sections of the IEE:-

- 5.3 Construction Impacts on Physical Environment.
- 5.4 Construction Impacts on Biological Environment.
- 5.5 Construction Impacts on Social-economic Environment.

The Contractor is responsible for the implementation of construction and rehabilitation activities for the site and for implementing the impact mitigation measures in the construction phase. The Contractor is also responsible for the Monitoring activities as detailed in Section 6.5 of the IEE. The contractor shall include staff to be specifically responsible for preparation and implementation of the Construction Environmental Management Plan (CEMP), which describes the Contactor's construction methodology and measures and plans for implementing the EMP. This includes maintaining a site diary and a grievance registry. The CEMP shall be approved by the Employer prior to the Contractor's mobilization to the site. The contractor will be required to report on the implementation status of the CEMP to the Employer.The damages due to the violation of the

stipulations by the Contractor shall be compensated and/or restored by the Contractor at his or her own expense.

2.1.2.2 Health and Safety

Health and safety procedures on the site shall comply with the Samoa Occupational Safety & Health (OSH) Act 2002 and any associated codes together with any additional requirements specified in the Contract. The Health and Safety plan shall be part of the CEMP as detailed in the IEE.

In order to formulate a specific and competent safety plan, the Contractor shall carry out a detailed risk assessment against the scope and nature of the contracted Facility and the particular site conditions. The documentation arising from this process shall contain a comprehensive schedule of all perceived risks and the proposed elimination and mitigation measures necessary to reduce the risk to a minimum. Risk assessment documentation shall form part of the auditable safety records.

The Contractor shall appoint a Site Safety Officer who will be responsible for the management and control of safety on site. All staff and workers will undergo a site safety training programme developed by the Contractor specifically for the Contract. Tool-box talks on particular safety hazards will be conducted by the Site Safety Officer on a regular basis in order to ensure that a proactive safety culture is maintained on the site through the period of the contract.

The Contractor shall provide a safety training induction to all visitors before they are permitted to enter the site.

2.1.2.3 Emergency Response and Callout

Throughout the contract period, the Contractor shall make contingency arrangements for 24 hour per day, 7 days per week availability of emergency response labour, plant and supervision to respond to emergency situations as may affect the Contract Facility, to ensure the safety and protection of them and adjacent property.

The Contractor is to develop a Site Wide Emergency Evacuation Plan. This plan is to apply to and be available for all personnel on site, Contractors own employees, and the employees of the Employer, Project Manager and any other contractors on the Site.

2.1.2.4 Quality Assurance

The Contractor shall establish, maintain and monitor a Quality Assurance Plan (QAP) which meets the requirements of ISO 9000 and ISO 9001. The QAP shall cover all elements of the permanent Facility.

The Contractor shall submit the QAP to the Project Manager prior to work commencing on site.

2.1.3 Resources

2.1.3.1 Contractor Supplied Materials

The Contractor shall supply all materials required for the execution of the Contract Facilities and for any temporary works and shall remove surplus materials from the site prior to completion of the Contract.

Materials awaiting incorporation into the Facilities shall be stored off site in secure premises until required for use on Site. On arrival at the Site, locations for storage shall be identified and planned by the Contractor so as to minimise interference with both the Facilities and other uses of the Sites.

2.1.3.2 Employer Supplied Materials

There are no Employer Supplied Materials

2.1.4 Key Personnel

The Contractor shall engage the Key Personnel and the Contractor shall promptly appoint suitable people (and any replacements) who shall be notified to the Project Manager in writing. Key Personnel are nominated in the Technical Proposal.

Technical personnel (engineers, technicians, etc) engaged in the works shall be registered under Institution of Professional Engineers of Samoa (IPES). This is a requirement of the Samoan Professional Engineers Registration Act. Refer to IPES website, *www.ipes.ws* for details.

2.1.4.1 Local Resources

As is standard practice in Samoa, the Contractor is expected to utilise local resources (labour, equipment, engineers, surveyors, etc) as much as possible, in so far as the skills and abilities of the local workforce allow.

Failure of the Contractor to correctly manage the local resources, which results in disruption and delays to the Project, is not deemed valid basis for a time extension claim.

2.1.4.2 Immigration / Work Visas

It is the responsibility of the Contractor to be fully acquainted and in compliance with the Samoa Immigration Department rules regulations and procedures applicable to immigration and work visa issues.

Failure to obtain work visas for the various staff required on the project is not reason for claims for either time or cost.

2.1.5 The Site

2.1.5.1 Site Definition and Access

The Project Site areas are contained in the areas indicated on the Drawings in Section 6-Supplementary Information.

The rights or customs of adjacent property owners and occupiers for access shall not be infringed by the Contractor.

2.1.5.2 Tolerances

The Contractor shall propose tolerances to be used for the Facilities that shall be subject to the Project Manager's approval.

2.1.5.3 Temporary Works

The Contractor shall ensure that all temporary works are properly designed and constructed so that the safety of persons and Plant has been properly taken into account. The Contractor shall be responsible for all costs associated with the design, construction, and performance of the temporary works.

2.1.5.4 Protection of Facilities

All finished Facilities shall be protected from damage which could arise from other construction activities.

Work shall not be carried out in weather conditions that may adversely affect the quality of the Facilities unless proper protection, acceptable to the Project Manager, is provided.

Facilities under construction and materials for such Facilities shall be protected from exposure to weather conditions, which may adversely affect the quality and performance of the Facilities and the materials.

2.1.5.5 Mobilization and Demobilization

Contractor shall furnish all the labor, materials, equipment and shall perform all work required for mobilization to and demobilization from the Project Site.

Mobilization shall include, but not be limited to: moving personnel, plant, and equipment to the Site; arranging for necessary Site utilities; establishing camps, shops, offices and administrative facilities; and obtaining all required permits, licenses, and other regulatory authorizations required for the construction of the Project.

A brief outline of the required permits, and the process and costs associated with obtaining them can be found at:-

http://www.doingbusiness.org/data/exploreeconomies/samoa/dealing-with-construction-permits/

Demobilization shall include, but shall not be limited to: removing all plant, equipment, and temporary works from the Site; disconnecting temporary utilities; relocating personnel from the Site; cleaning-up and restoring all areas occupied by the Contractor; closing out permits, licenses, and other regulatory authorizations; and disposal of all waste materials and excess construction materials which are not the property of the Employer.

2.1.5.6 Site Signage

Not Applicable

2.1.5.7 Working Hours

Normal working hours are Friday to Saturday 9am to 5pm. However, the Contractor is free to vary working hours provided there is no disruption to the adjacent villages outside normal working hours. Any work on Sundays or at night must be approved beforehand by the Project Manager. It is the Contractors responsibility to understand, and comply with, all local labour rules and laws.

2.1.5.8 Site Security

Because work will be carried out inside an operation station, work shall be done with utmost care to avoid tripping of any of running generators, and damages to electrical switchgear and mechanical equipment. Contractor must obtain prior approval from EPC for any work that requires them going into any of the electrical switchgear of operating generators.

2.1.5.9 Protection of Land, Flora and Fauna

Project has no impact on flora and fauna because all work will be done inside the power station.

2.1.5.10 Noise, Dust, Vibration and Damage or Nuisance

The Contractor shall minimise the generation of noise, dust, vibration and other potential causes of damage or nuisance, to the extent that is feasible given the nature of construction activities, statutory requirements and any other special protection specified in the Contract, statutory approvals and consents.

2.1.5.11 Dangerous Goods

No dangerous goods, explosives, chemicals, fuels or similar items shall be brought onto the Site unless the Contractor has advised the Superintendent of the intention to do so, and has complied with all statutory requirements for its safe storage and security.

The Contractor shall minimise the use of the Site for the storage of fuels, explosives and other dangerous goods as may be required for the construction of the Facilities and shall not use the site or allow access for any purpose not connected to the Contract.

Dangerous Goods are only to be stored in nominated and approved storage areas and must comply with the Samoa regulations governing such goods.

2.1.6 Design Principles

2.1.6.1 Functional Requirements

The Facilities shall be designed in an optimal manner such that they can be operated safely, reliably and economically and are fit for purpose. The design of the Facilities shall be such that they can be readily maintained, are secure, and are capable of continuous operation with minimum attention and maintenance.

The Project shall provide for the safe, reliable and efficient operation and dispatch of the turbine generators from the local powerhouse controls and from the Employers NCC.

Permanent access roads shall provide for all necessary transport, year-round, during construction, operation and maintenance of the Facilities.

The water conveyance systems shall provide for the required conveyance capacity safely and reliably under the specified head conditions.

Provisions shall be made for regular inspection and maintenance of all Facilities during the service life of the Project. Easy access and safety shall be provided for these operations.

2.1.6.2 Lifetime Requirements

The design of the electrical and mechanical systems shall be designed for a service life of at least 40 years with schedule maintenance in accordance with manufacturers' recommendations.

The design service life of a structure or equipment is the period for which it is to be used for its intended purpose. Regular maintenance is anticipated but structural reliability and operational integrity shall be maintained.

The Contractor is not responsible for guaranteeing the remaining life of the existing equipment or buildings that are rehabilitated under the Project. The Contractor is responsible for ensuring the design service life is achieved for all new civil, structural, mechanical and electrical elements provided by the Contractor.

The Contractor shall inform the Project Manager of specific parts or components of the design that have a shorter technical life than stated above. Such parts or components shall be included in the Facilities only as approved by the Project Manager.

All materials and equipment used in the Project shall be of acceptable quality and proven design, and shall be furnished by a recognized manufacturer or supplier.

2.1.6.3 Standards

All design and construction work, including the materials used and methods applied, shall be in accordance with one or more internationally recognized standards of practice. By definition, such standards comprise organizations such as the AS (Australian Standards), NZS (New Zealand Standards), ASTM (American Society for Testing and Materials), ISO (International Organization for Standardization), DIN (German Code), BS (British Standard), SS (Swedish Standard), EN (European Standard), or equivalent.

Should the Contractor request alternatives to the above standards, other relevant standards may be used subject to Employer's approval. Differences between the standards specified and the proposed alternative standards must be fully described in writing by the Contractor and submitted to the Employer for review and approval.

The latest editions on the Base Date of the standards and codes, including amendments, shall be used by the Contractor, unless expressly stated otherwise.

An English translation shall be submitted if the standards and codes proposed by the Contractor are in a language other than English.

All specific references to standards and codes throughout these Employer's Requirements are governed by this Part.

The Facilities shall be constructed in accordance with the laws of Samoa and associated Acts and Regulations. These include:-

- National Building Code 2002
- Electricity (Safety) Regulations 2010
- Occupational Safety & Health (OSH) Act 2002
- Environment Management Act

In order to achieve Regulatory compliance under the Electricity Regulations, the Facilities shall comply with the Electricity Regulations and AS/NZS 3000:2007 "Wiring Rules".

The standards under which the work is to be performed or tested are specified throughout these Employer's Requirements. Where such standards are in conflict with the provisions of these Employer's Requirements, the Employer's Requirements shall govern. In case of conflicting requirements that are not specified definitely in these Employer's Requirements between the standards of above authorities, such disagreements shall be resolved by the Project Manager, and the Project Manager's decision shall be final. It is understood that the latest revision or edition of such standards at the time of Tender shall apply.

In the absence of specific standards being nominated in the specifications, the following Standards shall apply:-

Australian/New Zealand Standards

AS/NZS	1170	Structural Design Actions
AS/NZS	1429.1	Electric cables - Polymeric insulated - For working voltages 1.9/3.3 (3.6) kV up to and including 19/33 (36) kV
AS/NZS	1768	Lightning Protection
AS	1824	Insulation coordination – Definitions, principles and rules
AS	1940	The storage and handling of flammable and combustible liquids
AS	2067	Switchgear Assemblies and Ancillary Equipment for Alternating Voltages above 1kV
AS/NZS	2312	Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings

AS/NZS	2373	Electric cables – Twisted pair for control and protection circuits
AS/NZS	2650	Common specifications for high-voltage switchgear and controlgear standards
AS	2676.2	Guide to the installation, maintenance, testing and replacement of secondary batteries in buildings: Sealed cells
AS/NZS	3000	Wiring Rules
AS/NZS	3008.1.1	Electrical installations – Selection of cables – Cables for alternating voltages up to and including 0.6/1 (1.2) kV.
AS/NZS	3010	Electrical Installations – Generating Sets
AS	3011.2	Electrical installations – Secondary batteries installed in buildings, Part 2: Sealed cells
AS/NZS	3080	Telecommunications installations - Generic cabling for commercial premises
AS/NZS	3155	Approval and test specification - Electric cables - Neutral screened - For working voltages up to and including 0.6/1 kV
AS/NZS	3191	Electric flexible cords
AS/NZS	3439.1	Low voltage switchgear and control gear assemblies
AS/NZS	3439.2	Low-voltage switchgear and controlgear assemblies - Particular requirements for busbar trunking systems (busways)
AS	3607	Conductors-Bare overhead, aluminium and aluminium alloy – steel reinforced
AS/NZS	3835	Earth potential rise - Protection of telecommunications network users, personnel and plant
AS/NZS	3947	Low voltage switchgear and control gear, (all relevant parts)
AS	4024.1	Safety of machinery, (all relevant parts)
AS/NZS	4026	Electric cables - For underground residential distribution systems
AS	4044	Battery chargers for stationary batteries
AS/NZS	4961	Electric cables – Polymeric insulated – For distribution and services applications
AS/NZS	5000	Electric cables – Polymeric insulated – For working voltages up to and including 0.6/1 (1.2) kV.
AS/NZS	60265.1	High-voltage switches - Switches for rated voltages above 1 kV and less than 52 kV
AS	60529	Degrees of protection provided by enclosures (IP Code)
AS	60870	Telecontrol equipment and systems (All parts)
AS/NZS	60898	Electrical accessories - Circuit-breakers for overcurrent protection for household and similar installations - Circuit-breakers for a.c. operation
AS	ENA	Guidelines for design and maintenance of overhead distribution and

	C(b)1	transmission lines.
AS	HB101	Coordination of power and telecommunications - Low Frequency Induction (LFI): Code of practice for the mitigation of hazardous voltages induced into telecommunications lines.

International Electrotechnical Commission (IEC)

IEC	11801	Information technology – Generic cabling for customer premises
IEC	14763	Information technology – Implementation and operation of customer premises cabling
IEC	24702	Information technology – Generic cabling – Industrial premises
IEC	60034	Rotating Electrical Machines – all relevant parts
IEC	60038	IEC Standard Voltages
IEC	60041	Field acceptance tests to determine the hydraulic performance of hydraulic turbines, storage pumps and pump-turbines
IEC	60044	Instrument Transformers
IEC	60051	Direct acting indicating analogue electrical measuring instruments and their accessories
IEC	60060	High Voltage Test Techniques
IEC	60076	Power Transformers
IEC	60085	Thermal Evaluation And Classification of Electrical Insulation.
IEC	60086	Primary Batteries
IEC	60099	Surge Arrestors
IEC	60137	Bushings For Alternating Voltages Above 1,000 V
IEC	60193	Hydraulic turbines, storage pumps and pump-turbines - Model acceptance tests
IEC	60228	Conductors of Insulated Cables
IEC	60255	Electrical relays
IEC	60269	Low-voltage fuses
IEC	60304	Standard colours for insulation for low frequency cables and wires
IEC	60308	International Code for Testing of Speed Governing Systems for Hydraulic Turbines
IEC	60354	Loading Guide For Oil Immersed Transformers
IEC	60364	Electrical installations of buildings
IEC	60502.1	Power cables with extruded insulation and their accessories for rated voltages from 1 kV (Um = 1,2 kV) up to 30 kV (Um = 36 kV) - Part 1: Cables for rated voltages of 1 kV (Um = 1,2 kV) and 3 kV (Um = 3,6 kV)
IEC	60502.2	Power cables with extruded insulation and their accessories for rated voltages from 1 kV (Um = 1,2 kV) up to 30 kV (Um = 36 kV) - Part 2: Cables for rated voltages from 6 kV (Um = 7,2 kV) up to 30 kV (Um = 36 kV)
IEC	60551	Determination Of Transformer And Reactor Sound Levels
IEC	60664	Insulation coordination for equipment within low-voltage systems (All Parts)

IEC	60715	Dimensions of low voltage switchgear and control gear
IEC	60793-1	Optical fibers – All Parts
IEC	60794	Optical fiber cables – Part 1-1: Generic specification – General
IEC	60794-1-2	Optical Fibre Cables - Generic Specification - Basic Optical Test Procedures
IEC	60794-4-1	Optical fibre cables - Part 4-1: Aerial optical cables for high-voltage power lines
IEC	60896	Stationary Lead-Acid Batteries
IEC	60898	Electrical accessories - Circuit-breakers for overcurrent protection for household and similar installations
IEC	60909	Short-circuit current calculation in three-phase AC systems
IEC	60934	Circuit breakers for equipment
IEC	61009	Residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBOs)
IEC	61660	Short-circuit currents in DC auxiliary installations in power plants and substations
IEC	62063	High-voltage switchgear and control gear - The use of electronic and associated technologies in auxiliary equipment of switchgear and controlgear
IEC	62271	High Voltage Switchgear and Control gear (All parts)
IEC	62305	Protection against Lightning

Institute of Electrical and Electronic Engineers (IEEE)

ANSI/IEEE	Std 1050	Guide for Instrumentation and Control Equipment Grounding in Generating Stations
ANSI/IEEE	Std 450	Recommended Practice for Maintenance, Testing and Replacement of Large Lead Storage Batteries for Generating Stations and Substations
ANSI/IEEE	Std 484	Recommended Practice for Installation Design and Installation of Large Lead Storage Batteries for Generating Stations and Substations
ANSI/IEEE	Std 485	Recommended Practice for Sizing Large Lead Storage Batteries for Generating Stations and Substations
ANSI/IEEE	Std 665	Guide for Generating Station Grounding
ANSI/IEEE	Std 80	Guide for Safety in AC Substation Grounding
ANSI/IEEE	Std 81	Guide for Measuring Earth Resistivity, Ground Impedance and Earth Surface Potentials of a Ground System
ANSI/IEEE	Std C37.101	Guide for Generator Ground Protection
ANSI/IEEE	810	Standards for Hydraulic Turbine and Generator Integrally Forged Shaft Couplings and Shaft Run-out Tolerances
ANSI/IC	S-87-	Standard for Fibre Optic Outside Plant Communications Cable

EA	640	
ANSI/IC EA	S-83-596	Standard for Fiber Optic Premises Distribution Cable

British Standards (BS)

BS	148	Unused Mineral Insulating Oils For Transformers And Switchgear
BS EN ISO	1461	Hot dip galvanized coatings on fabricated iron and steel articles
BS	6231	Specification for PVC-insulated cables for switchgear and controlgear wiring
BS	6651	Protection of structures against lightning.
BS	7354	Code of Practice for Design of high-voltage open-terminals stations, Section 7: Earthing.
BS	7430	Code of Practice for Earthing.

International Standards Organisation (ISO)

ISO	6826	Reciprocating Internal Combustion Engines - Fire Protection
ISO	8528	Reciprocating Internal Combustion Engine Driven Alternating Current Generating Sets – all relevant parts.
ISO	1000	SI units and recommendations for the use of their multiples and of certain other units

ITU

ITU-T Recommendation	G.650	Definition of a single-mode optical fibre cable
ITU-T Recommendation	G.652	Characteristics of a single-mode optical fibre cable
ITU-T Recommendation	G.655	Characteristics of a non-zero dispersion shifted single-mode optical fibre cable

ASTM

ASTM	A27	Specification for Mild to Medium-Strength Carbon-Steel Castings for General Application
ASTM	A36	Specification for Structural Steel
ASTM	A53	Specification for Welded and Seamless Steel Pipe
ASTM	A148	Specification for High-Strength Steel Castings for Structural Purposes
ASTM	A167	Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip
ASTM	A176	Specification for Stainless and Heat-Resisting Chromium Steel Plate, Sheet, and Strip
ASTM	A181	Specification for Forged or Rolled Steel Pipe Flanges, Forged Fittings, and Valves and Parts for General Service
ASTM	A213	
ASTM	A269	Specification for Soft Annealed Stainless Steel Tubing

ASTM	A275	Standard Method for Magnetic Particle Examination of Steel Forgings
ASTM	A282	Forged Stainless Steel Fittings, Socket-Welding and Threaded
ASTM	A285	Specification for Low and Intermediate Tensile Strength Carbon Steel Plates for Pressure Vessels (Plates 50 mm and Under in thickness)
ASTM	A312	Specification for Seamless and Welded Austenitic Stainless Steel Pipe
ASTM	A345	Specification for Flat Rolled Electrical Steel
ASTM	A388	Standard Practice for Ultrasonic Examination of Heavy Steel Forgings
ASTM	A403	Specification for Wrought Austenitic Stainless Steel Pipe Fittings
ASTM	A420	Specification for Stainless and Heat-Resisting Chromium and Chromium-Nickel Steel Plate, Sheet, and Strip for Fusion-Welded Unfired Pressure Vessels
ASTM	A516	Specification for Carbon Steel Plates for Pressure Vessels for Moderate and Lower Temperature Service
ASTM	A517	Specification for High Strength Alloy Steel Plates, Quenched and Tempered, for Pressure Vessels
ASTM	A582	Specification for Free-Machining Stainless and Heat- Resisting Steel Bars, Hot-Rolled or Cold-Finished
ASTM	A668	Specification for Steel Forgings, Carbon and Alloy for General Industrial Use
ASTM	A743	Specification for Casting, Iron-Chromium, Iron-Chromium-Nickel, and Nickel Base (Corrosion-Resistant) Alloy Castings for General Application
ASTM	B21	Specification for Naval Brass Rod, Bar, and Shapes
ASTM	B31.1	Power Piping
ASTM	B42	Specification for Seamless Copper Pipe, Standard Sizes
ASTM	B88	Specification for Seamless Copper Water Tube
ASTM	B127	Specification for Nickel-Copper Alloy Plate, Sheet, and Strip
ASTM	B230	Standard Specification for Aluminum 1350-H19 Wire for Electrical Purposes
ASTM	B232	Standard Specification for Concentric-Lay-Stranded Aluminum Conductors, Coated-Steel Reinforced (ACSR)
ASTM	B241	Standard Specification for Aluminum and Aluminum-Alloy Seamless Pipe and Seamless Extruded Tube
ASTM	B498	Standard Specification for Zinc-Coated (Galvanized) Steel Core Wire for Aluminum Conductors, Steel Reinforced (ACSR)
ASTM	B584	Specification for Copper Alloy Sand Castings for General Applications
ASTM	R0027 Vol	Standards Related to Nondestructive Testing Developed by ASTM Committees Other Than Committee E-7
ASTM	03.03	Nondestructive Testing

Other

ASCE	79	"Manuals and Reports on Engineering Practice No. 79," (Steel Penstocks)
ASME		American Society of Mechanical Engineers, "Boiler and Pressure Vessel

		Code," Division 2.
AWS		American Welding Society, "Structural Welding Code."
ASME	PTC Code 18	Hydraulic Turbines

All other equipment furnished under this section shall conform to the requirements of applicable Standards.

In addition to the Standards listed in the specification, and the Standards listed, above all other aspects of the Facilities shall be designed, manufactured and tested in accordance with the pertinent provisions of the codes and standards of the following listed institutes, associations and other organizations:

Name	Abbreviation
American National Standards Institute	ANSI
American Society of Mechanical Engineers	ASME
American Society for Testing and Materials	ASTM
American Welding Society	AWS
Australian Standards	AS
Australia/New Zealand Standards	AS/NZS
Institute of Electrical and Electronics Engineers	IEEE
International Electrotechnical Commission	IEC
Specifications for Inspection of Steel Castings for Hydraulic Machines	CCH-70-2
Steel Structures Painting Council	SSPC
New Zealand Standards	NZS

2.1.6.4 Design and Planning of the Facility

2.1.6.4.1 General

The Contractor shall be responsible for the design and planning of the Facilities in accordance with the Contract. The Contractor shall further establish and execute a Quality Assurance Plan to ensure and verify that his work is in accordance with the requirements of the Contract.

The Contractor shall prepare the design of the Facility which shall consist of the following:

- Tender Design, performed during the bidding process and submitted with the bidders Technical Proposal.
- Basic Design, performed immediately after the Contract is let.
- Detailed Design, performed before and during the construction of the Project.

The Contractor shall perform all additional field and laboratory investigations needed to fulfill the design and construction requirements given in the Employer's Requirements.

All design shall be performed in accordance with the requirements given in the Employer's Requirements. The Contractor shall design all Facilities and all necessary temporary works.

2.1.6.4.2 Contractor's Technical Proposal

The Contractor shall prepare and submit to the Employer for his review as part of the bidding process a Contractor's Technical Proposal that shall include the following as a minimum:

- A description of how the design requirements will be achieved including a description of design inputs and their sources, proposed design methods, techniques and software as well as a list of all references to be used for design of all Facilities., including:
    - Alternator
    - Control and protection design concept and equipment selections.
    - Approach to testing and commissioning
- A description of all exceptions to, or deviation from the Employer's Requirements.
- Principal outline drawings (plans, profiles, sections) of the project layout and all structures with principal drawings, schematic line diagrams etc. for all mechanical and electrical deliveries.
- Summary of all tests and investigations planned to be carried out in connection with the Detailed Design.
- Quality Assurance Plan.
- Any other information specified in Employer's Requirements.

Drawings shall be appended to the Contractor's Technical Proposal

The Technical Proposal shall include the following Schedules:

Supplier Schedules, with details of the supplier for all key equipment items for the project including:-

- Valves
- Turbine and Generator
- Governing System
- Excitation System
- Control and Protection System
- Electrical/Mechanical Design Services

Equipment Schedules, completed data sheets for all of the major equipment items. Blank data sheets for this purpose are provided for:-

- Excitation Systems
- Control and Protection
- DC Station Service (if needed)
- Power Transformer
- Step-up Transformer
- E&M Auxiliary Services

2.1.6.4.3 Design Documents and Construction Drawings

Design documents and construction drawings shall be prepared in the English language.

Design documents and all computations shall be initialled and dated by the designer and checker, and shall clearly state the Project name, calculation number and title, calculation description/objective, revision number (where revision 0 is the original submission), key assumptions, references, and a summary of the calculation conclusions/results.

All construction drawings shall be produced using the latest version of AUTOCAD. Each drawing shall be initialled by the designer and drafter as well as their respective checkers. The drawings shall include a revision number (where revision 0 is the original submission), a brief description of revision(s), and all revisions must be clearly identified on the drawing.

The Contractor shall have staff at the Site to prepare and to revise drawings and documents during construction as needed to document "as-built" conditions. Contractor shall provide three (3) copies and one (1) reproducible of final "as-built" plans for the civil works, electrical single-line drawings, and control logic diagrams, prior to issue of the Operational Acceptance Certificate for the whole of the Facilities.

All design documents and construction drawings shall be delivered in digital form to the Employer. In addition, unless otherwise specified, three (3) printed copies of each drawing and document shall be submitted to the Employer.

2.1.6.4.4 Units of Measure

The system of measurement to be used in the Project shall be in SI units. Angles shall be given in the 360-degree system.

The coordinate reference system to be used for the Facility shall be defined by a quadrant grid system. Each drawing shall contain a scale reflecting the appropriate meter spacing. The grid system shall be defined in accordance with the Samoa national grid system.

2.1.6.4.5 Seismic Design Requirements

All designs of the Facilities shall consider earthquake loadings such that performance of the Facilities is not adversely impacted under the design seismic event. The Plant shall be designed for the following Seismic Events:

- Strength and Stability: Annual probability of exceedance of 1 in 2500 years,
- Operability (including deformation, water tightness and other fit for purpose requirements): Annual probability of exceedance of 1 in 25 years

The design earthquake parameters shall be in accordance with those given in the National Building Code for Samoa. Alternatively, design to AS/NZS 1170 Part 5, Structural Design Actions - Earthquake, shall also be deemed to comply.

2.1.6.4.6 Basic Design

The Basic Design Report shall be developed from the Contractors Technical Proposal, updated as necessary. The report shall include all information required under Part 2.1.6.4.2

2.1.6.4.7 Detailed Design

The Contractor shall make the necessary Detailed Design for construction of the Project. For each feature of the project, the Contractor shall submit to the Project Manager for his review and approval, Detailed Design documentation to include as a minimum:

- A description of each structure/feature of the Facilities.
- Assumptions, design objectives, methods and philosophies adopted.
- Design criteria, parameters, loads and load cases used.
- Applicable codes, standards, and references used.
- A short description of each method of analyses, computer programs, etc. used.
- Calculations and results of the detailed design analyses for each structure/feature of the Facilities.
- Testing requirements and criteria.
- Detailed design drawings and specifications ready for construction

2.1.6.4.8 Design Submissions

The Contractor shall present the detailed designs, specifications and drawings for each aspect of the scheme. Each submission shall provide a complete package of information that is complete in itself and allows a full understanding of the design, drawings design criteria and applicable codes and standards that have been used in developing the design.

In general, the initial documentation for each aspect of work should consist of the items listed in the first five items above. Drawings will be rejected if this initial documentation is not available.

All drawings and design must be submitted for review. The Project Manager and his representatives will comment within the time prescribed in the Contract if there is any matter that they require attention or additional information is required to be submitted. If no comment is received from the Employer within the allowed time, the Contractor may proceed with the aspect of the Facilities covered by that particular submission.

2.1.6.4.9 Value Engineering

The Contractor may, at any time, submit to the Project Manager a written proposal which (in the Contractor's opinion) will, if adopted, (i) accelerate completion, (ii) reduce the cost to the Employer of executing, maintaining or operating the Facilities, (iii) improve the efficiency or value to the Employer of the completed Facilities, or (iv) otherwise be of benefit to the Employer.

2.1.6.4.10 Construction Methods

The Contractor shall prepare and submit to the Project Manager for his review and approval a Construction Method Report and Project Implementation Plan in conjunction with and related to the Contractor's Technical Proposal, Basic Design or Detailed Design as appropriate. The report shall include the following as a minimum:

- A description of how the construction requirements will be achieved.
- A description of construction methods to be used for all major works.

- A procurement plan for major equipment.
- Layout drawings for all temporary works.
- Principal items of construction plants to be used.
- Description of Quality Control and Quality Assurance.
- Construction Environmental Management Plan (CEMP).

The Contractor shall not start any major permanent construction work until the Contractor's Construction Method Reports, Project Implementation Plan and Construction Environmental Management Plan have been reviewed and approval by the Project Manager.

2.1.7 Construction Services

2.1.7.1 Scope of this Specification

This Specification covers requirements of the Contract for the services to be provided by the Contractor during the construction period.

2.1.7.2 General Requirements

This Specification provides an outline of the minimum construction standards required for the services facilities for the duration of the Project.

No accommodation facilities shall be erected on the Project sites, the expectation is that the Contractor will accommodate staff at commercial accommodation facilities.

2.1.7.3 Electrical Requirements

The Contractor shall provide all arrangements for temporary power supply for the site as required for the construction activities.

Where portable diesel electric generators are used for temporary power, they shall be fitted with residential class silencers and shall only be used between the hours of 7AM and 7PM to avoid disturbing local villagers.

2.1.7.4 Potable Water Supply

The Contractor shall provide all arrangements for the supply of potable water as well as disposal and treatment of used water.

2.1.7.5 Toilet Facilities

The Contractor can use plant toilet facility but in hygene way.

2.1.7.6 Fire Protection

Fire extinguishers shall be provided within each building.

2.1.7.7 Communications

The Contractor shall be responsible for providing all communications (connections and hardware) to the work sites and site offices.

2.1.7.8 Office Facilities

The Contractor shall provide the office facilities which he requires for the Project.

The office facility shall be sized to allow for project meetings, including staff from the Contractor, Employer, Project Manager and other Contractors employed on the project.

2.1.8 Pre-Commissioning, Commissioning, Guarantee Tests and Tests on Completion

2.1.8.1 General Requirements

During the erection and before Operational Acceptance of the Facilities, tests shall be performed by the Contractor under the direction of the equipment manufacturers' test engineers to determine whether the Employer's Requirements have been fulfilled.

This Part describes the minimum field tests to which the equipment shall be subjected. In addition to the tests listed below, the Contractor shall perform any other tests required by the Employer to establish conformance of the equipment with the guarantees and Employer's Requirements. The provisions of this Part augment any similar requirements in other Parts of the Employer's Requirements. In case of conflict, the detailed requirements of the particular equipment Part shall prevail. The waiver of any test shall not relieve the Contractor of its responsibility to meet fully the requirements of the Employer's Requirements. The Contractor shall coordinate with the Employer, and the equipment manufacturers involved establishing mutually satisfactory dates for field tests.

2.1.8.2 Responsibility

The Contractor shall be responsible for supervision and for test procedures for all field tests on the Facilities and shall furnish the necessary calibrated test instruments and equipment.

Test Equipment. All necessary test equipment shall be provided, including wire and cable for temporary connections. The test equipment shall meet the requirements of the standards specified herein and shall be properly calibrated in a qualified laboratory. The Employer shall be given catalogs and complete specifications of all test equipment and complete certificates of calibration. Test equipment shall remain the property of the Contractor following the tests.

2.1.8.3 Outline and Schedule of Tests and Test Plan

At least 90 days prior to the start of testing for each part of the Facilities, the proposed schedule for performing the specified tests shall be prepared and submitted to the Employer for approval. Not later than 60 days prior to the start of testing, a complete Test Plan outlining the test objectives and requirements, the proposed methods and the field procedures to be followed for the specified tests. This Plan shall be submitted to the Project Manager for review, including:

- Test procedures and scope of tests
- List of equipment required for each test.
- Number of skilled and unskilled personnel required for each test.
- Input required from other Contractors involved in the Project and the Employer
- Schematic and circuit diagrams showing connections to be used for each test.
- Test forms and summary sheets to be used for recording data.
- The minimum/maximum acceptable test values in order to meet specified requirements for the equipment.

After the Project Manager's review, six (6) copies shall be furnished to the Project Manager for distribution to participating parties.

2.1.8.4 Organization

During the testing period, starting from Pre-Commissioning through to the Guarantee Tests, the Contractor shall establish a start-up organization including all personnel, their responsibilities and the hierarchy of the organisation.

The Contractor shall appoint a Commissioning Manager, who shall be responsible for the Contractor's obligations during compliance checks, initial tests, system demonstrations and performance tests. The Contractor shall be solely responsible for testing of all systems and subsequent performance tests.

2.1.8.5 Factory Tests

- Factory tests shall be performed on generator and witnessed by Contractor and EPC representative.

The Contractor shall pay for the travel, hotel accommodation, transport, food and other incidental expenses for the Employer's representative. In addition, the contractor shall provide the Employers representatives with a $50 USD or equivalent per diem for the duration of the trip.

2.1.8.6 Testing Sequence

A system testing schedule shall be prepared by the Contractor and reviewed by the Project Manager.

As detailed in the General Conditions of Contract there are three phases to the Facilities gaining Operational Acceptance:-

1. Pre-Commissioning. Prior to the Contractor notifying the Project Manager that the Facility is Complete, the Contractor shall have completed all Pre-Commissioning.

2. Commissioning Tests

3. Guarantee Tests.

The Operational Acceptance Certificate will be issued on the successful completion of the Pre-Commissioning tests, Commissioning tests and Guarantee Tests.

Where testing, pre-commissioning and commissioning procedures are discussed in the various more-detailed Sections and Lots comprising the Employer's Requirements, those procedures are to be followed.

2.1.8.7 Completion of the Facilities

The following Sections of the Plant shall be completed with issue of Certificates of Completion and Operational Acceptance of the Facilities as permitted under the GCC: **Taelefaga Hydro Station 3rd 2MW Generator**

2.1.8.8 Pre-Commissioning

2.1.8.8.1 Compliance Checks

Prior to Pre-Commissioning, plant systems and subsystems shall be checked for compliance with drawings, specifications, and other Contractor's Documents. Procedures for compliance checks shall be included in the testing packages and shall be approved by the Project Manager. The Contractor shall be responsible for the implementation of compliance checks. The procedure shall include sign-off provisions by the Contractor and the Project Manager.

The compliance checks shall include "As Built" survey of the weirs and conveyance systems.

EPC will inspect and approve plant before testing and commissioning of the new generator and all associated equipment and switchgear.

2.1.8.8.2 Pre-Commissioning Tests

Prior to the Contractor notifying the Project Manager that the works are complete and ready for Commissioning, the Contractor shall have completed all Pre-Commissioning of the Facilities; including:-

- Hydrostatic tests.
- Point to point wiring tests.
- Insulation resistance tests.
- Power frequency withstand tests.
- Ductor tests on all high current carrying joints.
- Primary and secondary injection tests for all protection AC circuits.
- Plant control system software FAT and SAT tests.
- Operational tests of all balance of plant equipment.
- Pre-Start Tests.

In addition the following conditions shall have been met:-

- The conveyance system is complete and all equipment and personnel removed and all screens are in place. All tests required prior to filling with water or pressurisation have been successfully completed by the Contractor.
- The generating plant is complete and tested ready for watering up and livening

The Contractor shall also have completed flushing of the pipelines and penstocks and have removed all construction debris. A photographic record of the final inspection shall be handed to the Project Manager prior to proceeding with watering.

2.1.8.8.3 Dry Tests

Dry testing shall be carried out in the presence of the Project Manager or his nominated representative. The following tests shall be carried out:-

- intake gate shall be subjected to a full open and close cycle.
- intake valve shall be opened and closed using the remote close command from the powerhouse.
- The new turbine inlet valve shall be opened using the Unit PLC, and closed using the Unit PLC and protection system trips.
- governor system shall be dry tested to confirm correct operation of the spear valve and deflector positioning controls. Open/Close operating durations for the spear valves and deflectors shall be set in the governor control program and dry measurements of the actual opening and closing times shall be made. Correct operation of the governor shutdown trips from the Unit PLC and protection systems shall be confirmed.
- The Unit PLC start and stop sequences shall be tested as far as possible under "dry" conditions. During these tests the generator circuit breaker shall be racked out. The Contractor shall simulate the turbine speed using a signal generator to facilitate sequence tests.

Each test will only be deemed complete when the entire system under test operates correctly without any alarms, trips or abnormal or unexplained events occurring, this shall include all remote control and monitoring provisions from the Employers SCADA.

2.1.8.8.4 22kV System Energisation.

The 22kV switchboard and 6.6kV/22kV transformers (with the generator connections removed) shall be energized from the Employers 22kV distribution system and "soak" tested for 24 hours.

2.1.8.8.5 Generating System Wet Tests

Wet testing of the generating equipment shall be carried out in the presence of the Project Manager. The following tests shall be carried out:-

- The Unit PLC start and stop sequences shall be tested in a sequential manner and shall only proceed to the next stage after the preceding tests have been successfully completed.
- The first step shall be to pressurize the penstock up to the turbine inlet valve. This shall be undertaken in stages, of not more than 25m pressure head. At each stage the penstock shall be inspected and the pressure monitored to confirm no leaks exist before filling further.
- Once the penstock is fully pressurized the turbine shall be operated at speed no load and tests undertaken to confirm that the governor is correctly controlling speed. Shutdown tests shall be undertaken to confirm that the governor and inlet valve can safely isolate the turbine in the event of a fault. Following these tests a bearing heat run shall be carried out. The turbine generator shall be operated at speed no load until such time as the bearing temperatures have stabilized. The Contractor shall confirm that the bearing and oil temperatures are within expected limited.

- The generator shall then be excited and voltage regulator tests conducted. Phase sequence and phase angle measurements shall be made to confirm that the generator can be safety synchronized to the EPC system.
- The turbine generator shall be synchronized to the EPC system and systematically loaded and "drop load" tests conducted at 10%, 25%, 50% and 100% of full load. It shall be confirmed that the penstock pressure rise, and turbine overspeed levels are within acceptable limited.
- A 24hr heat run shall be conducted following the drop load tests.

2.1.8.8.6 Guarantee Tests

Following completion of the turbine generator commissioning tests by the Contractor, tests shall be made to demonstrate that the Facilities have achieved the following guaranteed performance:

- That any new generators achieve their guaranteed efficiency (this test is expected to be undertaken in the factory).
- A 168 hour Availability Factor test shall be carried out to demonstrate the reliability of the Plant supplied by the Contractor. If, during this test period, the generating plant cannot be operated at any load selected by the Employer for any reason attributable to the Contract Plant, then the Contractor shall remedy the defect and the test shall be restarted.

2.1.9 Contractors Documents

2.1.9.1 General

The Contractor shall submit Contractor's Documents as specified in these Employer's Requirements and other portions of the Contract. Unless otherwise specified below, the Contractor shall provide each Contractor's Document to the Project Manager within the time period specified.

Project Manager's review period and provision to comment shall be to confirm the Contractor's compliance with the Contract. It is intended that Project Manager shall have at least one review and comment opportunity for each Contractor Document.

Technical Submittals shall be provided as a complete package for each major system or subsystem. For avoidance of doubt the major system/subsystems shall be:-

- Generator and control equipment

The package shall include all relevant calculations, specifications of new generator, and drawings.

2.1.9.2 Monthly Progress Report

Within 28 days after the Commencement Date, and at monthly intervals (by the 5th day of each month) thereafter, the Contractor shall provide a Monthly Progress Report. Such report shall include project progress, problems, significant decisions, corrective action required, supplier status, schedule analysis, and other critical project information.

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2.1.9.3 Weekly Project Meeting

Project Manager may call weekly meetings of subproject ones construction and installation start. Contractor will report on status of each activity of subproject, discussing all problems and solutions.

2.1.9.4 Integrated Project Schedule

Within 28 days after the Commencement Date, Contractor shall submit an Integrated Project Schedule, including engineering, procurement, manufacturing, fabrication, transportation, construction, and testing, commissioning activities. The schedule shall be presented in electronic format.

The Contractor shall provide procurement, supply and installation plan of Works.

Monthly Progress Reports shall include a schedule update and progress tracking to compare the actual status of the Project with the scheduled baseline progress. Actual status shall be measured and reported using Earned Value techniques approved by the Project Manager.

2.1.9.5 Safety Plan

Within 42 days after the Commencement Date, Contractor shall provide a Safety Plan applicable to this Project.

The Contractor is responsible for the health and safety of all persons on the Site, including EPC staff assisting with installation. All necessary precautions shall be made to prevent accidents and personal injuries.

The Contractor shall make plans for dealing with emergencies at the Site, the Contractor's work areas, and during transportation. The plan shall include first aid, transporting accident victims to hospital, first aid education for employees, dealing with fires, etc. Such plans shall provide for all types of weather and working conditions which will be encountered at the Site and the Contractor's work areas.

In case of an accident connected with the execution of the Facilities, the Contractor shall immediately notify the Project Manager of the accident and shall provide full details of the circumstances and events regarding the accident.

2.1.9.6 Quality Assurance Plan

Within 42 days after the Commencement Date, Contractor shall provide a Quality Assurance Plan applicable to this Project.

The Contractor's Quality Assurance Plan shall comprise procedures for Quality Control and Quality Assurance. The plans shall include both design requirements and construction materials and workmanship requirements.

The Quality Assurance Plan shall define and document the Contractor's commitment to and policy for quality. The Contractor shall ensure that the policy and the associated procedures are understood, implemented and maintained at all levels in his organization, including all subcontractors. The Contractor's Quality Assurance Plan shall be based on well-established principles and proven performance.

The Quality Assurance Plan shall be supplemented as work proceeds with specific work and inspection procedures for all major activity. The work and inspection procedures shall include:

- Acceptance criteria, witness points and hold points specified in the construction requirements or in any standard or code adopted by the Contractor.
- Witness points for all the stages in the construction process where subsequent activities will disguise the quality and/or quantity of the previous activity thus making inspection and testing unfeasible, and/or where the subsequent activities will prevent correction of non-conformities.
- The Contractor shall issue relevant work procedures and inspection plans for the Project Manager's review prior to the commencement of each main activity, unless stricter demands are specified in special cases.

The Contractor's Quality Assurance Plan shall be submitted to the Project Manager for review. The Contractor shall monitor and approve his own work using the Quality Assurance Plan. The Project Manager will monitor the Contractor's ability to follow approved plans and procedures throughout the entire project. The Contractor shall provide copies of review reports and test reports to the Project Manager on a monthly basis.

2.1.9.7 Construction Environmental Management Plan

Not Applicable.

Within 42 days after the Commencement Date, Contractor shall provide a Construction Environmental Management Plan applicable to this Project.

The requirements of the Construction Environmental Management Plan are detailed in the IEE – refer Section 6 Part 4 - Supplementary Information.

The Contractor's Construction Environmental Management Plan shall be submitted to the Project Manager for review. The Contractor shall monitor and approve his own work using the Construction Environmental Management Plan. The Project Manager will monitor the Contractor's ability to follow approved plans and procedures throughout the entire project. The Contractor shall provide copies of review reports and test reports to the Project Manager on a monthly basis. The Project Manager may audit the Contractor's records at any time to verify that sufficient reviews, checks, and tests are being performed

2.1.9.8 Test and Commissioning Plan

Contractor shall provide Pre-commissioning and Commissioning plan of generator including load testing.

2.1.9.9 Guarantee Test Procedures

Contractor shall provide procedures to perform the guarantee tests.

2.1.9.10 Training Program

Contractor will provide training of EPC staff during installation of generator.

2.1.9.11 Materials

Current certificates of tests by manufacturers shall be available for inspection by the Project Manager. Such certificates shall relate to the materials delivered to the Site and Contractor’s work areas. Certified true copies of certificates may be submitted if the original certificates cannot be obtained from the manufacturer. A letter from the supplier certifying that the certificates are related to the delivered materials shall be submitted with the certificates.
Parts and/or materials which are to be assembled on the sites and Contractor’s work areas, shall be marked to identify the component parts.

Materials which are specified by means of trade or proprietary names may be substituted by the equivalent materials from a different manufacturer provided that the materials are of the same or better quality and comply with the specified requirements.

All materials and goods shall be stored strictly in accordance with the manufacturer's instructions so as to insure no deterioration occurs prior to incorporation in the Facilities.

Materials and goods shall be stored to prevent harm to people's health or the environment.

2.1.9.12 Supplier Information

Contractor to provide technical data on generator supplied, including shop drawings, erection drawings, and supplier manuals.

2.1.9.13 Purchase Orders

Unpriced purchase orders, shall be submitted by the Contractor for all purchased materials and equipment and any subcontracted services.

2.1.9.14 Spare Parts Lists

Contractor to recommend priced spare parts list of generator and installation to be purchased by EPC.

2.1.9.15 Notice(s) of Equipment Inspections

Not applicable.

Project Manager will review purchase orders and advise Contractor of any tests or inspection hold points specified in the purchase orders that Project Manager desires to witness. Contractor shall provide Project Manager reasonable notice to witness these inspections and tests designated to be witnessed at suppliers' works.

2.1.9.16 Shop Inspection and Test Reports

All shop inspection and test reports for Materials and Equipment shall be submitted to Project Manager for review.

2.1.9.17 Quality Control Reports

The Contractor shall provide quality control records of generator alignment, meggering, continuity wiring checks, etc.

2.1.9.18 Manufacturer Field Service Reports

Contractor to provide EPC any inspection report by manufacturer representative if they visit project during installation of generator.

2.1.9.19 As-Built Drawings

Contractor shall provide three (3) copies and one (1) original; P&ID's, of as built electrical drawings, and control logic diagrams, within 2 weeks after issue of Operational Acceptance Certificate.

2.1.9.20 Technical Documentation

2.1.9.20.1 General

The Contractor shall submit to the Project Manager Technical Documentation in accordance with the requirements of the Employers Requirements.

2.1.9.20.2 Specifications

Contractor shall submit to Project Manager for review all specifications issued by the Contractor to suppliers for procurement of major permanent equipment materials or subcontract services, conformed for purchase.

Contractor shall submit detailed technical specifications. The Contractor's specifications shall be used to ensure that construction of the Facilities satisfies the design requirements, achieves acceptable quality goals, and is consistent with good quality industry standard practices. Specifications shall include sections relevant to:

- Site preparation.
- Temporary works.
- Foundation modification if required
- Supply and Installation of generator
- Supply and Installation of electrical equipment.
- Any other necessary sections.

Construction specifications shall include:

- Materials to be incorporated in the Facilities.
- Standards and codes.
- Requirements for material placement and installation.

All technical specifications shall, as a minimum, be prepared in the same standard format and organization. The organization and format shall be consistent with international practice for projects of this type and acceptable to the Project Manager.

2.1.9.20.3 Outline Drawings

Outline drawings shall be drawn to scale and denoted with critical or major dimensions. Drawings shall include estimated weights, external forces, anchoring details, overall dimensions and information on oil, compressed air and cooling water requirements for the equipment.

2.1.9.20.4 Detail Drawings

Detail drawings shall consist of general assembly Drawings, subassembly Drawings and details to demonstrate fully that all parts will conform to the provisions and intent of these Employer's Requirements and to the requirements of their installation, operation and maintenance. The Drawings shall show all necessary dimensions and fabrication details, including type and grade of

materials, the design of welded and bolted joint connections and tolerances on fits and clearances; all field joints and subassemblies in which the Contractor proposes to ship the equipment; locations and sizes of auxiliary connections for oil, grease, water and air; and, piping and process flow diagrams. Detailed specifications shall be submitted by the Contractor for the design of all major components and for other features or details when requested, including the stress levels calculated by the Contractor. The Project Manager shall have the right to request the Contractor's design calculations, which clearly indicate all assumptions, methods and results. The Contractor shall provide English translations of any non-English text as required to explain the calculations to the Project Manager satisfaction.

2.1.9.20.5 Full-Line Diagrams

Diagrams shall show the power connections, location of instrument and control transformers, and connections to transducers, meters, relays and instruments.

2.1.9.20.6 Schematic/Elementary Diagrams

Diagrams shall demonstrate the operation of the supplied control equipment. They shall include:

- Range, operation and setting for time delay relays and timers.
- Set and reset points for process instruments.
- Protective relay settings.
- Fuse and circuit breaker ratings.
- Control voltage and, if source of control voltage is not supplied by manufacturer, recommended overcurrent protection and conductor size for supplying the circuit.

2.1.9.20.7 Wiring Diagrams

Diagrams shall show the point-to-point interconnections of the control and power equipment. Control devices and terminal blocks shall be shown in their correct relative positions. One side of the terminal blocks shall be clearly identified for external wiring connections and shall be free of any manufacturer's wiring. Control devices and terminal blocks shall be identified in accordance with schematic/elementary diagrams.

2.1.9.20.8 Front-of-Panel Layouts

Equipment and nameplates mounted on the fronts of control cabinets and switchboards shall be shown. Diagrams shall be drawn to scale.

2.1.9.20.9 Nameplate Schedules, Meter Scales, Engravings and Switch Handles

Schedules for all front-of-panel devices and equipment shall be provided. Nameplate schedules shall include dimensions and lettering size. Scale markings for meters and other indicating instruments shall be shown. Escutcheon plate and legend plate engravings and type and color of switch handles shall be shown.

2.1.9.20.10 Design Calculations

The design calculations shall define the basic design approach, assumptions, criteria used and the calculated stress levels in sufficient detail to demonstrate that the equipment meets the specified requirements and to provide adequate information for trouble-shooting of the equipment.

Detailed calculations for all protection settings shall be provided

2.1.9.20.11 Bills of Material

A list of equipment shall be submitted for each major assembly or sub-assembly and shall include the names of manufacturers of articles and auxiliary equipment to be incorporated in the work, together with description, part number, ratings, performance characteristics and other significant information as necessary to allow the Employer to obtain replacement parts. A separate list of equipment shall be provided for each printed circuit board and sub-assembly incorporated into the work, identifying the individual components mounted on the board. Bills of Material shall be provided listing the spare parts, special tools and maintenance equipment.

2.1.9.20.12 Cable Schedules

Tabulations showing the routing of all cable and wire used for power, control and instrumentation circuits shall be provided. Cable tabulations shall be prepared showing the type, size and number of conductors in each cable. Each cable shall be given a unique cable identifier. The cable tabulations shall list the equipment to which each cable is connected (From/To) and the cable tray in which it is routed.

2.1.9.20.13 Functional Block Diagrams

Block diagrams shall be provided that show the functional configuration of the main components of a system including the communication network and paths interconnecting them. The functional block diagram shall be presented in a manner that conveys the functionality of the system. Interfaces to main structures and equipment components in the Project shall be shown as well as interfaces with Employer's remote facilities.

2.1.9.20.14 Termination Drawings/Schedules

All terminations of power, control and instrumentation cable external to an electrical component, panel or cabinet shall be shown either on termination drawings or on schedules. Information shall include the terminal block designation, cable identifier, cable characteristics (i.e., size, number conductors/pairs/triads, shielding) conductor identification (e.g., number, color), number of spare conductors and to where the other end of the cable is routed (with references).

2.1.9.20.15 Logic Diagrams

A complete set of logic diagrams describing the software used in microprocessor-based controllers shall be provided. The logic diagrams shall be provided as follows:

- Analog Control Loops. These diagrams shall be provided in accordance with ISA standard format.
- Sequencing Controls. Controls used for sequencing logic shall be provided in Boolean or ladder-type format.

2.1.9.20.16 Instructions

2.1.9.20.16.1 General

The Contractor shall submit written detailed instructions for shop assembly and testing; handling and storage; installation, operating and maintenance and field commissioning procedures of check-out, start-up, initial operation, testing and test run for each item of equipment. The instructions shall be submitted as early as possible so that final reviewed copies can be made available to the field for use in planning their work well in advance of actual installation and operation. After review, ten (10) complete, durable bound copies of the final instructions shall be furnished.

2.1.9.20.16.2 Shop Assembly and Testing Procedure

A step-by-step procedure shall be submitted outlining the details of the checks to be made before and after shop assembly and testing of the equipment to demonstrate that the requirements of these Employer's Requirements and other parts of the Contract have been fulfilled. The shop assembly and testing procedure shall be submitted in a tabular form itemizing each test, indicating the results expected in accordance with the design and leaving space for the actual observation during assembly and testing. The test procedures shall include test values to be used, maximum/minimum acceptable test results and reference to accepted industry standards. The limitations, if any, of the shop tests shall be fully explained and shall be approved by the Project Manager.

2.1.9.20.16.3 Handling and Storage Instructions

Not applicable.

Detailed instructions, with illustrations, diagrams and weights, for handling, storage and care of equipment at the site shall be submitted. The instructions shall include:

- Identification of parts requiring special outdoor, indoor or temperature or humidity-controlled storage for both long- and short-term storage;
- Space requirements for outdoor, indoor and temperature- or humidity-controlled storage for both long-term and short-term storage;
- The procedures to be observed in unloading, placing, stacking and blocking of equipment;
- Rigging and lifting procedures;
- Maintenance procedures for both long- and short-term storage including maximum recommended storage period for items stored outdoors;
- Periodic rotation of components, where required;
- Application of protective coatings; and
- Cleaning of protective coatings and/or corrosion prior to installation.

2.1.9.20.16.4 Installation Instructions

Detailed instructions for the installation of the equipment shall be submitted together with reduced-size copies of applicable Drawings showing the erection sequence. The instructions and Drawings shall include information on handling and slinging the major pieces of equipment including weights, erection tolerances and special precautions to be observed during installation.

2.1.9.20.17 Operating and Maintenance Instructions

Detailed operating and maintenance instructions, which shall include reduced-size copies of all Drawings, applicable parts lists and catalogs covering all equipment furnished and which may be needed or useful in operation, maintenance, repairs, dismantling or assembling and for repair and identification of parts for ordering replacements, shall be submitted. The operating and maintenance instructions shall include a complete set of performance curves clearly showing the operating limits over the full range of operating heads.

Operating and maintenance instruction manuals shall be written to provide a complete and clear text, which can be used directly throughout the service life of the equipment without any addition by the Employer. Terminology and designations used in the instruction manuals shall be exactly the same as used on the Contractor's Drawings.

The sequence of subjects within the instructions, the arrangement of paragraphs and the use of headings shall permit an overview of the entire subject matter as well as permit quick reference to particular subjects.

The operating and maintenance instructions shall clearly state the salient features of the equipment supplied and the operation of the electrical controls. All required liquid levels, flows, pressure settings and settings for all auxiliary protective devices shall be included. A troubleshooting chart, maintenance timetable, lubrication diagrams and disassembly, reassembly and adjustment procedures shall be provided.

2.1.9.20.18 Reports

The Contractor shall furnish final reports related to the new generator including testing, initial operation, load rejection and load acceptance tests and the index and capacity tests.

2.1.9.20.19 Photographs

Not applicable.

The Contractor shall furnish progress photographs of the shop and field erection work done. Photographs shall be taken at approximately quarterly intervals. Photographs shall be approximately 200 mm by 250 mm in size including a margin on one 250 mm side for binding. Approximately twenty-five (25) views each of the turbine and generator and five (5) views each of the inlet valves, governing system and excitation system will be required. Each photograph shall contain upon its face the date, the name of the manufacturer and the title of the view taken.

2.1.9.21 Submission of Technical Documents

The following drawings and document listing is intended to summarize the information and data to be submitted by the Contractor to Project Manager. In the case of differences between this list and the specific submittal descriptions of the Employer’s Requirements, the specific descriptions shall govern.

Document	Submitted for
A. Basic Design (Updated Tender Design)	
Powerhouses	
General Arrangement Drawings	Approval
Plant layout drawings	Approval
22kV and 6.6kV one line diagram	Approval
Control System Architecture	Approval
Interface with SCADA system	Approval
B. Detailed Design	
General	
Updated Basic Design	Review
Powerhouses (all existing)	
AC and DC Schematic diagrams	Review
Relay diagrams	Review
Wiring diagrams	Review
Cable schedules	Review
Panel layout drawings	Review
Termination drawings/schedules	Review
Lighting and general power layout drawings	Review
P&IDs	Review
Hydraulic schematics	Review
Plant general arrangement drawings	Review
Plant manufacturing and shop drawings	Info/Record
Logic diagrams	Review
IO Schedules	Review
C. Other Documents	
Project Control/Management	
Construction method statement	Review
Specifications	Review
Progress report	Review
Drawings list	Review
Project schedule	Review
Safety plan	Review
Quality Assurance Plan	Review
Construction Environmental Management Plan	Approval
QA/QC procedures	Approval
Shop test/inspection reports	Info/Record

Document	**Submitted for**
Pre-commissioning, commissioning and guarantee test procedures	Approval
As-Built design drawings	Info/Record
Recommended spare parts and maintenance equipment list	Review
Final Design Report	Review
Final Construction Report	Review
D. All other documents specified in the various parts of the Employer's Requirements, not already described above	Review

Notes:
2.2 Submittals

1.1 "Info/Record" refers to documentation that normally will not be reviewed by Project Manager during the design phase but is required for the testing, commissioning and operation phase.
1.2 "Review" refers to documents that Project Manager will receive and comment on during the design, construction or testing, commissioning and testing phase, as applicable.
1.3 "Approval" refers to documents Project Manager shall approve or give acceptance as set forth in the Contract.
1.4 If documents are required earlier to support Project Manager related activities such as: permitting interface with other Employer contractors' activities, etc., Contractor shall use all reasonable efforts to support these requirements.

2.3 SPECIFIC REQUIREMENTS

2.3.1 General

Only the generator of Unit No 1 will be replaced. Turbine and electro-mechanical controls will remain.

The layout of the Taelefaga powerhouse is shown in the Figure below.

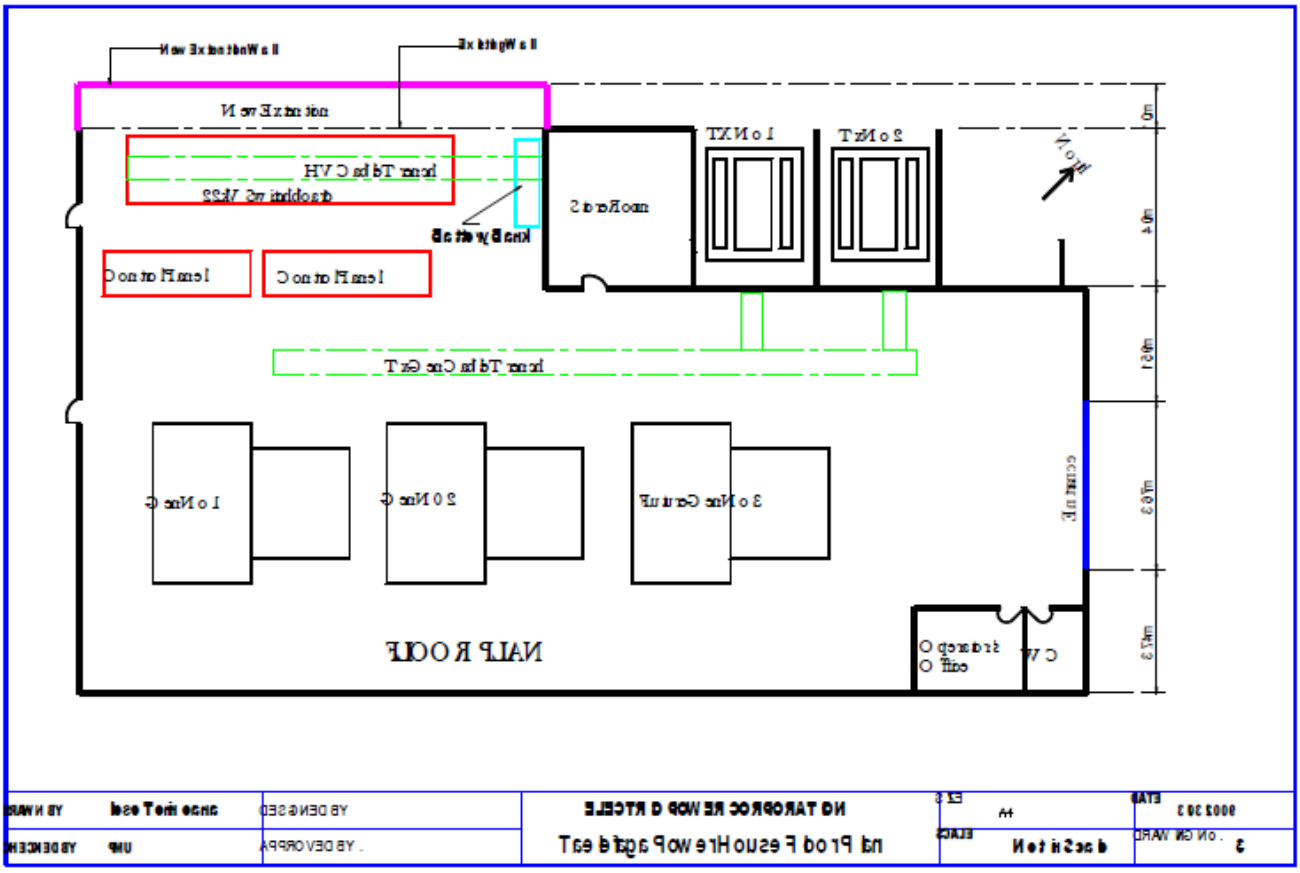

Figure 3: Taelefaga powerhouse layout

Figure 4: Generator No 1 is closer to this side of picture. Spare bay is for 3rd Generator installed under a different contract.

The type of turbine for the two existing generators; is single horizontal shaft Pelton wheel turbine manufactured by DUMONT, France in 1992. The turbine is equipped with two needles and deflectors. The deflectors are coordinated with the actuators of needles. Net head is 299meters. The output of turbine is 2,060kW at 750rpm. A butterfly valve at water inlet side and by pass valve in by pass line are also fitted.

Table 1: Turbine Data

Component	Data/Information	Unit
Turbine type	DUMONT	
Year of manufacturing	1992	
Location of manufacturer	France	
Height of water fall	299	m
Maximum water flow	1.85	m^3/s
Nominal power	2060	kW
Rotation	750	rpm
Run away speed	1350	rpm

Figure 5: Taelefaga's Turbine

2.3.1.1 Governor

Existing governor control system remains.

The governor for the two existing generators was replaced in mid 2014 with a new PLC governor; "Rivermaster" governor model number DG-4 for multi-jet Pelton machines supplied from Control Electronics Ltd, in New Zealand. Governor for the third generator will be of the similar type.

2.3.1.2 Generator & Exciter

Provide a new 2500kVA, 750rpm generator suitable to existing turbine. The generator shall be complete with excitation system, lubrication system (if required), cooling water system (if required and instrumentation. The generator inertia shall not be less than the existing generator.

This replacement generator and exciter will have similar technical characteristics with the old generators.

Table 2: Generator Exciter Data

Component	Data	Unit
Generator type	Synchronous	
Connection type	YN	
Nominal Power	2500	kVA

	2000	kW
Voltage	6600	V
Rated current	218	A
Power factor	0.8	
Rev/min	750	Rev/min
Allowable overspeed Rev/min	1150	Rev/min
Frequency	50	Hz
Ambient rating	45	Deg Celsius

Figure 6: Photo inside plant showing Generator No 1 from exciter end

2.3.1.3 Generator Phase and Neutral Equipment

New generator will be connected to existing neutral earth transformer. Bidder must inspect and access existing earth transformer for reuse.

2.3.1.4 Step-up Transformer

Existing step up 6.6/22kv power transformer will be used. This is a new transformer recently installed to replace an old one.

Table 3: Existing Transformer Data

Component	Data/Info	Unit
Apparent power	2500	kVA
Transformation ratio	6600/22000	V
Intensity of the primary and secondary currents	218.7/62.75	A
Transformer cooling system	ONAN type	
Vector type	YNd11	

Figure 7: Taelefaga Station Step-Up Transformer pad for third generator

2.3.1.5 Control Panel

Existing generator control panel will be reused. Bidder to inspect panel for any repairs or upgrade to be done to reuse.

Figure 8: Taelefaga Plant's Exiting Generator Control Panel

2.3.1.6 Civil work:

Generator will be installed on same pad that old one is installed. Selected Bidder will design and modify hold down bolts if new generator don't match with old one hold down bolts. Hold down bolts shall be tested

2.3.1.7 Valves

All valves remain same.

2.3.1.8 Control and Instrumentation

The Contractor shall:-

- Use same unit control system.

2.3.1.9 Communications

The Contractor shall use same communication system.

2.3.1.10 Protective Relaying System

The Contractor shall:-

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- Use All cablings to comply with Section 6 Part 2.4.11
- Use same Generator protection relay using existing SEL700G Generator Protection relay with PT & VT wiring and installation, testing and commission into the 22kV Feeder Circuit Breaker control compartment.

- Complies with Section 6 Part 2.42.4.9.

2.3.1.11 DC System

Use same plant DC system for generator & auxiliaries. The Contractor shall:-

- Reuse existing DC system. System may be upgraded to include third generator & auxiliaries by contractor for installation of a 3rd Generator.
- Use same 110V DC system in compliance with Section 6 Part 2.4.10.

2.3.1.12 22kV Switchgear

The existing 22kV switchgear is retained.

Use same Areva manufactured switchgear. The Contractor shall:-

- Perform routine tests complying with Section 6 Part 2.4.12 to verify that the switchgear is in good condition.
- Slot in the Protective Relaying System specified in Section 6 Part 2.3.1.12
- Do all cabling & terminations

2.3.1.13 Miscellaneous

Taelefaga's Overhead Beam and lifting system

Max carrying capacity is 14 tonnes. Break and motor for lifting system needs to be replaced by Contractor to be able to use this lifting system.

2.4 M&E General Requirements

2.4.1 Contract Wide Requirements

2.4.1.1 Design Responsibility

The Contractor shall assume full responsibility for a coordinated and adequate design of all equipment specified and shall ensure that such equipment conforms to the best engineering practice for the operating conditions specified. When requested by the Project Manager, the Contractor shall furnish complete information as to the maximum stresses and other criteria used in the design. All equipment shall be proportioned and arranged to fit with proper clearances into the powerhouses.

2.4.1.2 Units of Measurement

The units of measurement to be used throughout this Contract shall be metric in accordance with ISO 1000:1992 "SI units, etc." On drawings or printed pamphlets where other units have been used, the equivalent metric measures shall also be shown.

2.4.1.3 Site Conditions

2.4.1.3.1 General Conditions

The equipment shall be suitable for operation at, and ratings shall be based on, the following conditions:

- Maximum outdoor ambient temperature for design purposes 40°C
- Minimum average over 24 hours 23°C
- Maximum average over 24 hours 29°C
- Design water temperature 25°C
- Relative Humidity 80 - 97%
- Average annual rainfall 3500 mm
- Thunder storm days per year (estimate) 50

2.4.1.3.2 Transport Limitations

The contractor shall be free to select the route for delivery of plant to site and shall be responsible for determining any limitations on route selections imposed by weight and/or size limits on roads, bridges, etc. Road down to power station from main road is very narrow and steep.

2.4.1.3.3 Water Conditions and Corrosion

Power station is right at coast of Fagaloa Bay. It is exposed to salt spray wind from ocean.

Corrosion resisting steel or bronze shall be used for bolts and nuts when either or both are subject to contact with river water and/or frequent adjustment or frequent removal, such as adjusting bolts for packing glands on removable screens or strainers, on adjustable bearings, etc.

2.4.1.3.4 Labels and Plates

The Contractor shall supply all name plates, caution plates and labels for the safe and efficient operation of the plant.

Each item of plant shall have permanently attached to it in a conspicuous position a nameplate or label of approved size and pattern. Before the manufacture of any nameplates or labels, the Contractor shall submit to the Project Manager a copy of the nameplate and label design standard for approval. All data, name plates and instruction plates on plant and cubicles shall be in the English language. Any other language labels may be provided for construction and commissioning purposes but shall be temporary and removed prior to completion.

2.4.1.3.5 Standards and Workmanship

All materials shall be new, of a first-class nature. All materials shall comply with the latest relevant authorised standards for testing materials unless otherwise specified or permitted by the Project Manager.

All workmanship shall be of highest class throughout to ensure smooth and vibration free operation under all possible operating conditions, and the design, dimensions and materials of all parts shall

be such that the stresses to which they may be subjected shall not render them liable to distortion, undue wear, or damage under the most severe conditions encountered in service.

All parts shall conform to the dimensions shown, and shall be built in accordance with, the approved drawings. All joints, datum surfaces and mating components shall be machined and all castings shall be spot faced for bolts and/or nuts. All machined finishes shall be shown on the approved drawings.

All screws, bolts, studs and nuts and threads for pipe shall conform to the latest standards of the International Organization for Standardization (ISO) covering these components and shall all conform to the standards for metric sizes.

The Contractor shall use exclusively the standard and size system presented in his Tender and accepted and incorporated in this Contract.

2.4.2 Governors

2.4.2.1 Type and Description

Reuse existing Governor System.

Turbine governors shall be provided complete with actuator, governor cubicle, transmitters, motor-driven oil pumping units, pressure accumulators, operation oil, oil piping, digital speed sensing equipment, hydraulic control module, power packs and all parts and accessories required to make a complete unit for regulating the speed and controlling of the associated turbine.

The governor shall:

a) be a state of the art equipment utilizing a standard programmable logic controller (PLC) for governor control functions and an oil hydraulic system with pressure accumulator for actuation of the spear valve/wicket gates; deflectors and turbine inlet valve.
b) maintain the speed of the associated turbine generator in a stable manner and return the speed to steady state condition following a system disturbance.
c) combine with the deflector and spear valve or guide vanes to limit surges and overpressures within the penstock safety margins.
d) positively contribute to the overall electricity grid stability.
e) permit operation of the associated turbine generator in parallel with other turbine generators in the system, or in stand-alone operation into a varying, isolated load.
f) be capable of adjustment, while the unit is in operation, to optimize performance during commissioning and periodic testing.
g) be compatible with the auto-synchronizer and manual synchronizing.

The governor shall be protected from the effects of electrostatic discharge, radiated electromagnetic fields and conducted or induced fast transients or bursts of noise.

2.4.2.1.1 Performance Requirements

2.4.2.1.1.1 Stability

Governing systems shall be capable of controlling with stability the speed of the associated turbine generator unit when operating at rated speed and no-load or when operated at rated speed with isolated load at all power outputs, including maximum output. The governing system shall also be capable of controlling with stability the power output between zero and maximum power output inclusive when the generator is operating in parallel with other generators in the plant or in the transmission systems. The governing system shall be deemed stable, if the hydraulic system of the turbine and water conduits is inherently stable, when:

- The magnitude of the sustained speed oscillation caused by the governor does not exceed -0.15% to +0.15% of rated speed with the generator operating at rated speed and no-load or when operating at rated speed and isolated sustained load with the speed droop set at 2% or above.

- The magnitude of the sustained power output oscillation caused by the governor does not exceed -0.2% to +0.2% of the rated power output of the turbine with the speed regulation set at 2% or above and with the generator operating under sustained load demand in parallel with other generators, which are themselves capable of operating in parallel with other generators.

2.4.2.1.1.2 Dynamic Characteristics

After full load rejection, the following dynamic performance of the governing system shall be achieved:

- The number of occurrences of a peak speed over 3% of the rated speed shall not exceed 2 times.
- The duration time from the point at which servomotors first travel in opening direction to the point at which the speed fluctuation does not exceed -0.5% to +0.5% of the rated speed shall not be more than 40-s.

The time interval between a speed change of 0.01 to 0.02% of the rated speed of the unit to the first detectable movement of the turbine control servomotor(s) for a sudden load change of more than 10% of the rated power output of the turbine, shall be not more than 0.2-s.

2.4.2.1.1.3 Speed Dead Band

The total magnitude of the sustained speed change within which there is no measurable change in the position of the turbine control servomotor(s) at rated speed of the unit shall not exceed 0.02% of the rated speed at any gate opening. The minimum speed change in percent of rated speed to which the governor will respond (sensitivity) is defined as one-half the measured dead band.

2.4.2.1.1.4 Permanent Speed Droop

The permanent speed droop shall be capable of adjustment, while the unit is in operation, to values between 0 and 10% when the speed adjustment is set to give rated speed with full wicket gate opening.

2.4.2.1.1.5 Stability Adjustment

The dynamic performance of the governing system shall be achieved with proportional, integral, and derivative function blocks, each with independent continuously-adjustable gains as described below. The range of adjustment shall be selected to suit the dynamic requirements of the controlled system. The range of adjustable gains shall not be less than:

Proportional gain Kp:	0 – 20 s
Integral gain Ki:	0 - 10 per s
Derivative gain Kd:	0 - 5 s

The gains shall be adjustable while the governing system is in operation and shall be automatically adjusted by the governing system depending on its operating mode. Independent adjustable gains shall be provided in the proportional and integral function blocks.

2.4.2.1.1.6 Range of Speed Adjustment

The governor shall permit fully opening the spear valve/wicket gate when the unit is operating at speeds up to 110% of normal speed with a speed regulation setting at 10% or less. With the unit operating at zero power output, it shall permit operating the unit at speeds down to 90% of normal speed, with zero speed regulation setting. It shall permit synchronizing the generator for parallel operation with other generators at operating speeds between 90% and 110% of normal speed by local or remote adjustment of the speed setting. The rate-of-change of speed settings shall be software adjustable and, as a minimum, shall include a range of variation between 20 and 40-s to reduce the setpoint from maximum to zero, or vice versa.

2.4.2.1.1.7 Frequency-Phase Follower

To facilitate synchronizing the unit with the network, the governor shall be provided with a frequency-phase follower which shall control the opening of the turbine control servomotor(s) until the frequency of the generator matches closely with the frequency of the network.

2.4.2.1.1.8 Power Controller

The governor shall be equipped with a power controller which shall develop a governor error signal based on a power setpoint, real power feedback, and speed. The power controller shall be initiated by operating the appropriate control switch on the electric governor or from a remote control command from the plant Control System. This mode of operation shall only be in effect while the machine's speed remains within an adjustable speed band. If the machine's speed falls out of the speed band, then the governor logic shall change its operating mode to speed control and remain in this mode until a change is initiated.

2.4.2.2 Control Modes

One 2-position switch shall be mounted on the front of the control cubicle to permit the selection of the following control modes:

- Automatic control to maintain the system frequency or unit output within the limits specified in 2.4.2.1.1 Performance Requirements.
- Manual local control by adjustment of control switches on the governor electrical cubicle.

The governor shall permit the following types of turbine shut-down:

- Normal shut-down initiated by local or remote control with full spear valve/wicket gate closure followed by breaker tripping at zero power output.
- Partial shut-down to speed no-load in the event of load rejection or breaker tripping. This partial shutdown shall automatically occur when the governor detects that the generator circuit breaker has opened.
- Emergency shut-down with maximum deflector/spear valve; wicket gate closing rate in the event of equipment failure.

In the event of a fault in the governor system the associated turbine generator shall be shut-down.

2.4.2.3 Governor Control Processor

The governor functions shall be controlled by a programmable logic controller (PLC). The same PLC shall be used for turbine generator start/stop control, load control, protection of the turbine generator against mechanical faults and alarming. The PLC shall be located in the Unit control panel and comply with the technical requirements referenced in Part 2.42.4.7 Control and Instrumentation Systems.

2.4.2.4 Speed Sensing System

Speed sensing systems shall consist of a toothed disc mounted on the top of the generator shaft, proximity sensor pick-ups and a transducer for providing an analogue speed measurement to the PLC and digital outputs for turbine generator overspeed protection and any key start/stop interlocks required by the Contractors design.

Speed sensing systems shall be able to detect complete stop and creeping of the associated turbine generator. Speed sensing using the generator frequency as measured at the generator line terminals shall also be provided and shall be utilized by the governor system as the primary speed sensing mechanism for frequency tracking, synchronisation and on load operation. The generator frequency sensing shall only be used once the generator has been excited by the AVR. The transition between speed sensing systems shall be bumpless.

Speed sensing systems shall be capable of operating without damage at the maximum turbine runaway speed and shall be designed, mechanically and electrically, for continuous operation.

In the event of a fault in the speed sensing system the associated turbine generator shall be shut-down.

2.4.2.5 Spear Valve/Deflector/Wicket Gate Position Transmitters

Reuse existing.

The turbine spear valve/deflector or wicket gate servomotor position shall be derived by electronic position transducers connected to the PLC. The accuracy of measurement shall not exceed 0.2%. All necessary mounting brackets, hardware, and linkage to translate turbine spear valve/deflector or wicket gate servomotor movement into a linear 4-20mA signal shall be provided. The signal shall be reverse acting, i.e. 0-100% servomotor position shall be scaled 20-4mA. In case of loss of the feedback signal, the governor shall shut down the associated turbine generator.

2.4.2.6 Hydraulic Control Interface

Reuse existing.

The spear valve/deflector or wicket gate position shall be controlled by the governor via a continuously variable analogue output to the electro-hydraulic interface. The electro-hydraulic interface shall consist of an analogue servo-amplifier, electronic proportional valve, and a linear position feedback device measuring the position of the distributing valve. The proportional valve shall be controlled by a 4-12-20mA error signal directly from the analogue servo-amplifier. The servo-amplifier shall utilize the governor analogue output and the distributing valve position feed back to generate the proportional valve control signal. The measuring accuracy of distributing valve position feedback device shall not exceed 0.1% and shall have a frequency response to 10kHz. The proportional valve shall have a linear flow characteristic throughout its operating range and a frequency response to 15Hz.

2.4.2.7 Oil Pumps

Reuse existing.

The governor hydraulic unit shall have one main oil pump and one backup pump. The capacity per minute of the main pump shall not be less than 3.5 times the total active oil volume of the wicket gate servomotors.

The backup pump shall be sized to permit black starting of the turbine generator without the use of local service AC supply, and for controlled shutdown of the turbine generator in the event of the main pump failing.

Each pump shall be of the screw type and shall be self-priming under the maximum oil pressure. The main pump shall be direct-connected to a 400V 3-phase AC, low-starting-current, induction type motor, designed for full-voltage direct on line starting. The backup pump shall be direct connected to a 110V DC motor.

An unloading valve, relief valve, check valve, and all necessary valves for automatic and manual operation shall be provided for each pump. An unloading valve shall be provided to by-pass the oil when the pressure has reached maximum normal working pressure. A relief valve of sufficient capacity to pass the full delivery capacity of all three pumps at a pressure 10% above the unloading valve pressure setting shall be provided as a safety device. The discharge from the relief valve shall be routed back to the sump. Hand-operated valves shall be provided to isolate any pump from the oil pressure system and permit its removal without losing oil pressure.

2.4.2.8 Governor Accumulator

Reuse existing.

The accumulator shall be manufactured to an internationally recognised pressure vessel standard, and shall be of bladder type. High pressure nitrogen shall be used to charge the accumulator. The accumulator shall be capable of operating two complete spear vale/deflector or wicket gate valve open-close operations and one inlet valve close operation with the oil pumps inoperative. The accumulator shall be fitted with a pressure transmitter-indicator, high trip, high low and low trip pressure switches, oil level transmitter-indicator and level alarm switches.

2.4.2.9 Sump Tank

The governor hydraulic power pack shall be provided with a sump tank which shall form the base for the oil pumps or other suitable arrangement subject to approval of the Project Manager. The capacity of the sump tank shall not be less than 1.1 times that required to contain all of the working oil that can be discharged back into the sump by completely discharging the pressure tank and the oil that can drain from the governing system back into the sump tank by gravity flow.

The sump tank capacity shall be sufficient to maintain the oil level within an adequate working height during operation. The sump tank shall be provided with suitable access openings and with a fine mesh screen strainer or individual pump suction strainers through which all oil pumped shall pass. A stainless steel drip tray shall be provided with sufficient capacity to hold all the oil in the lubrication system.

The strainer or strainers shall be readily removable for cleaning without draining the sump tank. The sump tank shall be equipped with a flush-mounted oil-level indicator, a filler connection, a drain connection with oil drain valve, and connections for circulating the oil through an oil purifier. Oil level switches shall be also provided for high and low level alarms and shut down of the oil pumps on very low oil level.

The sump tank shall be equipped with tank breathers. Breathers shall have a filtration rating equal to or better than the oil purification system filter. Exhaust from breathers shall be free from oil mist.

The Contractor shall supply a first fill of all governor oil.

2.4.2.10 Instruments

The governing system shall be provided with the instruments listed below, mounted on the governor hydraulic unit or on the PLC control panel.

- Governor oil pressure gauge.
- Governor oil pressure transducer.
- Governor sump oil level low trip, low alarm and high alarm switches.
- Governor oil temperature RTD.

- Transducers for remote telemetry of wicket gate positions.
- Devices for control and protection of each governor oil pump and motor starters.

2.4.2.11 Specified Spare Parts

The Contractor shall furnish spare parts for the new generator and auxiliaries supplied under this contract.

Generators

2.4.3.1 Type and Description

Generator shall be totally enclosed, 3 phase, rotary field, salient pole type synchronous machines. Cooling shall be open circuit air through the generator with rotor mounted fans. The heat shall be ducted from the generator to the powerhouse exterior. The generator enclosure shall be IP 23 of IEC60034-5.

The rated continuous output of the generator shall be matched to the generator being replaced.

The terminal voltage shall be 6.6 kV phase to phase.

The generators shall be suitable for direct coupling to the existing turbines.

The maximum continuous output of the generators shall be possible at any voltage between 95 and 105% of rated voltage and at any frequency between 49 and 51 Hz from 0.8 lagging to 0.95 leading power factor. The generator shall be suitable for operation in parallel with the other generators in the existing power system.

2.4.3.2 Efficiency

The generator average efficiency shall be greater than 91% over the range 15% to 100% of Rated output and at unity power factor. The Contractor shall provide a minimum average generator efficiency over the range 15% to 100% of Rated Output.

The minimum acceptable generator efficiency at rated output, and at unity power factor, is 95%.

The Contractor shall provide an efficiency curve for each generator with their offer. This curve shall show the generator efficiencies at 25%, 50%, 75% and 100% of rated output for unity and 0.8 power factor.

2.4.3.3 Voltage Regulation

The inherent voltage regulation (without AVR) of the generator at 0.9 lagging power factor shall not be greater than ± 30 percent. Guaranteed values at 0.9 lagging and 1.0 power factors shall be given in the Tender.

2.4.3.4 Insulation and Temperature Rise

Insulation of the generator windings shall be classified as Class F. With the turbine at the rated design output as defined in IEC 60085 and the generator at 0.9 lagging power factor, the temperature rise shall not exceed the limit for Class B insulation as defined in IEC 60085.

2.4.3.5 Unbalanced Load

The generator shall be capable of a negative sequence I_2^2t value of 20 for transient operation under system fault conditions and continuous operation of 10% negative phase sequence current.

2.4.3.6 Generator Connections

The generator shall be star connected with three (3) terminals brought out at the neutral side and three (3) terminals at line side of the stator winding. Both the line and neutral terminals shall be insulated for full line voltage.

2.4.3.7 Temperature Detectors and Thermometers

The generator shall be provided with RTD temperature detectors. At least three (3) for the stator winding and one (1) for each thrust and journal bearings. These shall be located where it is anticipated the maximum temperatures will occur. The RTDs shall be 3 wire or 4 wire Pt 100 type and wired to the Generator Terminal Box.

2.4.3.8 Vibration Monitoring

Each of the generator bearings shall have vibration monitoring. The analogue values shall be monitored and provided with alarm and trip contacts suitable for interfacing with the Employers control and protection system. The alarm and trip limits will have a starting multiplier suitable for the machine. The monitors shall have one 4-20 mA analogue signal output per axis for connection into the Employers control system. All of the vibration monitor interfaces shall be wired to the Generator junction box. Vibration Monitoring pickup heads shall be located in close proximity to the bearing and must monitor movement in the direct vicinity of the bearing. If necessary sensors with pickups remote from the transmitter shall be used.

2.4.3.9 Structural Design

It is preferable that the generator shall be designed so that it is possible to replace the winding at the Site. If this is not possible, it should be noted in the Tender offer. The design of the generator shall be such that the unit can be lifted as a complete unit to the lay down area for maintenance purposes.

a) Stator

The stator frame shall be made of welded steel plate with sufficient reinforced ribs. The stator cores shall be built up with high-permeability and low specific loss silicon steel lamination.

Preferably, the stator core shall be adequately keyed or detailed to the stator frame. Any deviation from this shall be specifically noted with the Tender offer. The stator frame shall be provided with lifting lugs suitable for applying slings for lifting the stator or generator assembly by crane or lifting gear.

Within the generator housing, the stator terminals shall be copper, and shall be of the bolt-clamped type for connection to the power cable terminals.
The stator coil conductor shall be electrolytic copper with a conductivity not less than the value for annealed copper specified in the approved standard. The coil insulation shall be properly vacuum and pressure impregnated with high-grade resin so that the insulation becomes a dense, homogenous mass free from voids. The insulation shall become reasonably plastic by the application of heat or shall otherwise be of such nature that the coil ca be placed in or removed from the slot without injury. The insulation shall also have adequate corona shielding with a semiconducting compound, and shall withstand specified continuous temperature without injury. The coils shall be form-wound and interchangeable.

The end portions of the coils and the connection shall be rigidly supported and braced to prevent vibration and distortion under stresses caused by the most severe short-circuit condition to which the generator may be subjected.
The Contractor shall notify in their Tender any areas where the proposed new generators do not comply with the requirements of Section 6 Part 2.4.5.2 "Stator Rewinds".

b) Rotor

The poles are integral with the polar wheel.

The entire rotor shall be designed to safely withstand all mechanical stresses to be imposed by the maximum runaway speed of the turbine for fifteen minutes. Special case shall be taken to prevent the end turns from deforming or slipping due to the centrifugal stresses on the interconnections. The poles shall be provided with copper damper-bars and a complete damper winding. The rotor leads shall be connected to the brushless exciter mounted on the generator shaft.

The Contractor shall notify in their Tender any areas where the proposed new generators do not comply with the requirements of Section 6 Part 2.4.5.3 "Rotor Field Windings".

c) Shaft

The generator shaft shall be forged carbon or alloy steel properly heat-treated. The shaft shall be of ample size to operate safely at any speed up to the maximum runaway speed of the unit without detrimental vibration or distortion.

The exterior cylindrical surface of the shaft and couplings shall be accurately and smoothly machined all over and polished at bearing surfaces. The end of the shaft shall be arranged for suitable coupling to the turbine.

The coupling dimensions shall match the existing turbine coupling and shall substantially conform to ANSI Standard B49.1 *"Shaft Couplings, Integrally Forged Flange Type for Hydroelectric Units"*. The Contractor shall supply all bolts, tools and special plant necessary for field assembly of the coupling.

The Contractor shall make all necessary provisions to install on the shaft the speed signal generator for the Turbine Speed and Output Controller, the brushless exciter and the separate flywheel is required.

The entire turbine generator set shaft line shall be designed to ensure that the first critical speed is at least 25% greater than the runaway speed.

The shop alignment test of the fully assembled generator and turbine shall be carried out the Contractor witnessed by the Project Manager. Any corrections to the generator or turbine shafts for proper alignment shall be made immediately, if necessary. The Contractor shall cooperate to effect this so as to minimise any delay and to adhere to the schedule.

d) Bearings

The generator shall be provided with thrust bearings and journal bearings. A single combined thrust bearing for both turbines will also be acceptable. At least one bearing housing shall be isolated electrically from the support pedestal and the remainder of the machine. All bearings shall be oil lubricated type.

The bearings shall be of the forced-lubrication type, and the Contractor shall ensure that the bearings are adequately lubricated during starting after long periods (more than four months) of shutdown and shall not rely on the inherent oil film remaining from the last run. An AC powered duty, and 24V DC powered standby, lubrication pump shall be provided. The bearings and lubrication oil system shall be designed so that neither the bearing or the oil temperature shall exceed 75^{o}C under continuous normal operation at an ambient powerhouse temperature of 40^{o}C. If oil cooling is required for the lubrication system, suitable corrosion resistant oil coolers of ample capacity shall be provided in the system.

All necessary apparatus including piping, valves etc to complete the lubricating oil system shall be provided. An oil sight gauge shall also be provided on each oil reservoir. Draining facilities for the oil and water system shall be provided.

The thrust and journal bearings shall be designed to withstand safely and without damage the natural retardation of the turbine-generator unit from the maximum runaway speed to rest without the use of the generator brakes.

The thrust and journal bearings shall be designed to withstand safely and without damage the natural retardation of the turbine-generator unit from a full load rejection to rest with both the AC and DC lubrication pumps inoperative.

e) Generator Housing

A steel plate housing shall be furnished for the generator and shall be sufficiently rigid to prevent objectionable vibrations.

The generator housing shall be arranged to permit easy removal for the purpose of inspection and maintenance.

f) Generator Heaters

The Generator shall be provided with suitable type space heaters of adequate capacity to prevent moisture condensation while the generator is shutdown. The space heaters will automatically turned on when the generator shutdown and switch off when generator is running. Power supply to the heaters is three-phase 415 volt AC or single-phase 240/250 volt AC.

g) Bedplate

Preferably, the generator components shall be mounted on soleplates to facilitate site alignment. The generator shall be fully assembled at the Contractor's shop.

2.4.3.10 Generator Neutral Earthing

The generator shall be provided with a suitable grounding transformer and resistor. The primary rated voltage of the transformer shall be at least 1.3 times the line voltage of the generator. The resistor and transformer shall be designed with an impedance to match three times the capacitive impedance of the generator circuit including the generator cables and transformer. The generator earths and the generator neutral earthing transformer shall all be tied to a common station earthmat. The grounding transformer and resistor shall be suitable for outdoor mounting and shall be enclosed to prevent harm to personnel.

2.4.3.11 Accessory Leads and Control Cabling

Leads within, or on the generator and housing including leads for excitation, search coil, controls, space heaters, temperature detectors, speed signal generator, current transformer secondaries and other accessories shall be furnished and installed in rigid galvanised steel conduits complete with necessary mounting and fittings. Leads shall terminate with terminal blocks in the Generator Connection Box to be placed at one convenient location on the generator housing.

2.4.3.12 Terminal Boxes

The main and neutral terminals shall be brought out to terminal boxes on the side of the generator that shall also house the voltage and current transformers. The main and neutral cable connections shall be made at these terminal boxes. All other electrical interfaces to the generator including CT and VT secondaries, instrumentation, protection and controls shall be made at the Generator Terminal Box, mounted on the generator.

The terminal boxes shall be totally enclosed and provided with removable front panels for Plant inspection and termination.

2.4.3.13 Generator and Surge Protection Cabinet

The surge diverter assembly shall comply with IEC 99 and IEC 71 and shall be suitable for protection of the generator windings under the specified conditions. Each surge divertor shall be fitted with a surge counter.

A suitable cabinet shall be provided to house the generator surge divertor. The cabinet shall form a complete enclosure and allow for adequate ventilation and maintenance. The Plant within the cabinets shall be arranged to allow for easy maintenance and replacement.

2.4.3.14 Specified Spare Parts

The Contractor to provide prices to supply generator spares listed below. A set is defined as the total number of each component required for one generating system. One set of spare parts shall be provided. Where listed components differ between generators supplied, one set shall be provided for each design of generator.

- One set of bearings.
- Four spare stator coils.
- One set of diodes.
- Other items recommended by the Contractor.

2.4.4 Excitation Systems

2.4.4.1 Type and Description

Excitation systems shall, where available, be supplied by the original generator manufacturer, and shall match the performance and functionality of the original excitation system and voltage regulator.

If the original generator manufacturer no longer exists, or cannot supply replacement excitation components, then a third party "aftermarket" supplier of excitation systems may be used. Where-ever possible the third party product shall be a model specifically designed for the recipient generator.

The following clauses are intended as general guidance for the replacement excitation systems. It is recognized that some variance may be necessary in order to match available excitation systems to the particular generators. The Contractor shall provide details of any material deviations with their tender offer.

The capacity of the excitation system shall be more than 110% of capacity required for the generator. The ceiling voltage of the excitation system shall be not less than 175% of the rated field voltage under the field winding temperature at 75°C. The response ratio of the system shall be to less than 2.0.

The excitation system and voltage regulating shall be able to operate safely at any speed put the frequency corresponding to the maximum momentary speed rise when full load is rejected.

2.4.4.2 AC Exciter

New generator will be supplied with a new exciter.

2.4.4.3 Rotating Rectifier

The existing rotating rectifier shall be retained if compatible with the Contractors proposed excitation system design. If the rotating rectifier needs to be replaced then the replacement shall be:-

- of three-phase full bridge silicon diode type connected to the AC exciter.
- provided with protection devices to suppress overvoltage and transient voltage in the rectifier circuit. The rectifier diodes and protection devices shall be mounted rigidly on the holder ring so as to withstand centrifugal force of the maximum runaway speed, and shall withstand all site ambient temperatures.
- designed that when one diode is faulted, the generator shall be able to keep running safely until the next scheduled servicing shutdown. A diode failure detector shall be provided to given protection and alarm for the excitation system.

2.4.4.4 Voltage Regulator

The voltage regulator shall consist of an automatic voltage regulator (AVR). The automatic voltage regulator shall be of high speed, quick response static transistor amplifier type and shall include a power system stabiliser. The AVR is to be housed in the generator junction box. The AVR shall preferably be able to be interfaced to an external device by a digital communications link. This link shall be a standard protocol such as Profibus, Modbus or DeviceNet.

The AVR shall operate in one of two modes. When operating isolated from the power system, the AVR shall operate in voltage setpoint mode. The voltage setpoint shall be adjusted from "Raise" and "Lower" inputs from the Employer control system. An adjustable droop shall be present which allows the machines within the scheme to operate in parallel. When operating in parallel with the power system, the AVR shall be able to control the power factor of the output. The power factor setpoint shall be set by the Employer Control System. The AVR shall adjust the relevant parameter linearly over the range. The selection between the two operating modes shall be made by an input driven by the Employer Control System. The outputs must be limited so that machine capability is neither exceeded nor artificially limited.

The automatic voltage regulator shall continuously respond with high speed to correct any change in generator voltage and maintain the generator terminal voltage under steady state conditions within plus or minus 2.5 percent (± 2.5 %) without hunting for any excitation value within the normal operating range.

The AVR shall include a Volt/Hertz limiting function. Provision shall be made to de-energise the field quickly if a fault is identified in the generator.

All adjustments shall provide a wide range of settings to allow the full use of the generator capability.

2.4.4.5 Protection and Alarm for Excitation System

The protection for the excitation system shall be classified into two groups by the nature and extent of faults. If a serious fault is detected the excitation system shall be tripped and the generating unit will be shut down. When a fault is not so serious, the faulted device shall be isolated from the system without interruption of the generator excitation and an alarm shall be raised.

The protection and alarm system for the excitation system shall be designed to be compatible with the protection and alarm system for the generating Plant. The protection and alarms shall be provided for, but not limited to, the followings:-

a. Protection (Trip)

- AVR power source, failure
- Two (2) diodes on one phase of rotating rectifier, fault
- AVR, fault
- Field overvoltage

b. Alarm

- One (1) diode on one phase of rotating rectifier, fault
- Field circuit, ground

2.4.4.6 Specified Spare Parts

The Contractor shall furnish spare parts for the excitation systems as listed below. A set is defined as the total number of each component required for one excitation system. One set of spare parts shall be provided. Where listed components differ between excitation systems supplied, one set shall be provided for each design of excitation.

- One set of all plug-in type electronic components and printed circuits cards.
- Other items recommended by the Contractor.

2.4.5 Turbine Generator Accessories

2.4.5.1 Type and Description

If required by the Mechanical or Electrical Specific Requirements elements of the existing generators shall be replaced with new components. This section details the technical requirements for any replacement components.

2.4.5.2 Stator Rewinds

2.4.5.2.1 Stator Coils

New stator coils shall incorporate modern practice in design, material, and workmanship. Coils shall be of the multi-turn type designed to minimize eddy current loss. The strands shall be annealed copper, free from splinters, flaws, rough spots, or short radius bends. Coil leads shall not be cut or tailored for any particular slot and shall be designed for use in any slot.

Strands shall be continuous (splice free) within the entire mean turn length of each coil and shall be insulated with continuous filament glass or dacron glass fibers, or mica tape, bonded to the copper with a suitable bonding agent. The strand insulation system shall be thermally stable at the maximum temperature encountered in operation at rated maximum loading conditions and be rated for 7.2kV. Conductor strands shall be sized and arranged to minimize eddy and circulating current losses.

The slot and end winding portions of the assembled strands shall be bonded into a homogenous structure of controlled size using heat and pressure. Strand bonding resins shall have properties and characteristics to prevent bond failure due to the mechanical, thermal, and chemical effects associated with thermal cycling while operating within the Class F temperature limits for which the winding is to be designed. The turns shall be insulated with multiple layers of mica tape in combination with suitable backing materials.

Ground insulation shall consist of multiple overlapped layers of mica splitting and/or mica flake tapes applied continuously and of equal thickness throughout the entire length of the coil. All mica tapes shall be constructed with a glass or polyester fabric backing material. A suitable protective covering tape shall be applied over the ground insulation mica tape. The voltage stress on the ground wall insulation shall not exceed 65 volts per mil.

After the application of all insulation, the coils shall be given appropriate drying treatments to remove absorbed or trapped moisture and gases from the insulation system.

After drying treatments, the coil insulation shall be completely filled with a solventless polyester or epoxy resin using a vacuum-pressure or mechanical impregnation process. After impregnation, the coil insulation system shall be cured by the application of heat and pressure to the slot and end winding portions of the coils. Slot portions shall be sized to closely controlled dimensions and end portions shall be restrained with suitable pressure devices to assure a well-compacted insulation structure.

Slot portions of the stator coils, and a suitable distance beyond, shall be treated with a semiconducting compound capable of giving positive electrical contact between the treated portions of the coil surface and the entire length of the core slot walls. This semiconducting treatment shall be designed to eliminate corona discharges between coil and slot surfaces and between top and bottom coil sides.

A voltage grading semiconducting compound shall be applied to a suitable portion of the stator coil surface extending outward from the semiconducting treatment. This voltage grading semiconducting treatment shall be of a length and resistivity to limit coil surface voltage gradients to levels well below surface discharge (corona) onset levels under normal operating voltage stresses.

The new coils shall all be subjected to the following tests:-

- Strand Continuity and Strand Insulation.
- Turn Insulation Dielectric Test.
- Ground Insulation Dielectric Test.
- Power Factor Tip Up Tests

Each coil shall be given a unique identification. A permanent record for each coil shall be kept whether the coil is included in the finished winding or not. The record shall include the results of all coil tests.

2.4.5.2.2 Resistance Temperature Detectors

Standard 3-wire platinum resistance temperature detectors (RTD) of 100 ohms at 0ºC plus or minus 1ºC shall be supplied for installation in the stator windings. A minimum of two (one being a spare) RTDs per phase per circuit shall be furnished for each unit.

Two RTDs shall be installed at each selected slot location between the top and bottom coil midway between the top and bottom of the core. One of the RTDs shall be designated a spare to be used in the event the primary RTD fails.

Each RTD shall be supplied with three connecting leads of sufficient length for installation to a new generator accessory lead terminal box. Leads shall be solder-spliced; mechanically spliced leads shall not be used. The portion of the temperature detector in the slot shall have a semiconducting coating.

2.4.5.2.3 New Circuit Rings

New circuit rings, complete with all necessary connections, taps, adapters, braces, supports, and materials for making the necessary line and neutral connections between the windings and the generator terminals shall be provided.

The stator winding shall be wye-connected. Each phase of the stator winding shall consist of coils, with neutral leads and the common main leads brought out within the generator housing.
Construction
The new circuit rings, supports, and connecting leads shall be designed for installation in the same general location as the existing equipment, without alteration of the air baffling system or modification of structural parts. All factory joints shall be brazed in accordance with the requirements of AWS A5.8.

The circuit rings and connections shall be insulated for 7.2 kV with full Class F insulation or better composed of mica or glass tapes.

2.4.5.2.4 Fillers, Wedges, Ties, And Blocking Material

All material in the slot or used in bracing the winding shall be of an "approved" Class F or higher material.

All filler strips shall be fabricated from semiconducting material. The semiconducting material shall be impregnated throughout and shall not be coated on top of an insulating backing. A center filler between the two coil sides in a slot shall be supplied of such a thickness as to prevent interference between the coils in the straight part extension. RTDs shall be installed in place of the center filler in specified slots.

A bottom filler shall be used between the bottom coil side (furthermost from the bore) and the bottom of the slot. Slot side fillers shall be used between the coil sides and the slot sides.

Spring-type filler material shall be installed between the front filler and the wedge.

Stator slot wedges shall be manufactured from NEMA Standard LI1, Grade Gll material. The slot wedge cross sectional shape shall match the wedge groove shape of the stator laminations. Wedge width shall result in a snug, sliding fit when placed in position prior to driving over top fillers.

End winding bracing material shall be Class F and shall include resin-impregnated conforming material, blocks, and glass twine. The conforming material shall be dacron felt and shall be impregnated thoroughly with resin before use between the coils. The blocks shall be glass based and shall be used when the space cannot be filled with resin-impregnated dacron felt. After installation the ties are to be saturated with the resin.

Following installation of the stator coils, fillers, wedges, ties and blocking, the stator shall be painted with red alkyd.

2.4.5.2.5 Specified Spare Parts

The Contractor shall furnish spare parts for the rewound stators as listed below. A set is defined as the total number of each component required for one stator. One set of spare parts shall be provided. Where listed components differ between stator windings supplied, one set shall be provided for each design of winding.

- Four spare stator coils.
- Other items recommended by the Contractor.

2.4.5.3 Rotor Field Windings

Field windings shall be annealed copper, free from splinters, flaws, rough spots, or short radius bends

The insulation materials used shall be rated Class F.

The turn insulation shall be an Aramid paper treated with a "B" staged epoxy resin that is heat bondable.

The pole body insulation shall be made of a high strength, Class F material.

New leads shall be designed, fitted, and brazed to the field coils to allow for better mechanical integrity, and shall be compatible with the existing lead configuration.

After the rotor poles are completely assembled, the complete assembly shall be cleaned, and the coils painted with red alkyd.

2.4.5.4 Current Transformers

Use existing CTs.

Current transformers shall be manufactured to IEC60185 and shall use standard IEC winding ratio's. Protection and instrumentation current transformers shall use 1 A secondary and metering transformers 5A secondary. Current transformers shall have a standard insulation class of 11 kV and a basic impulse insulation level of not less than 75 kV and shall be cast resin type of either ring or bar configuration.

The IEC relaying accuracy class at 50-Hz shall be at least 5P20 for protective circuits and class 0.2 for measuring or metering circuits. Current transformers for the excitation system may use non-standard winding ratio and accuracy class if required by the excitation system manufacturer.

All secondary leads shall be brought out to the generator terminal cabinet and terminated on clearly marked 600 V terminal blocks. The terminal blocks shall have special provisions for short circuiting each current transformer secondary winding.

Standard application data shall be furnished in accordance with IEC 60185. Curves and data to be furnished for the transformers shall include, but not be limited to the following:

- Ratio and phase-angle correction curves.
- Short-time thermal and dynamic stability current ratings.
- Excitation current curves showing "knee" point voltage for each type and rating.

2.4.5.5 Voltage Transformers

Generator voltage transformers shall be manufactured to IEC60186 and shall have a winding ratio of 6.6kV/√3:110/√3. Three phase voltage transformers shall comprise three individual single phase transformers, each of cast resin type.

Voltage transformers shall have a standard insulation class of 11 kV and a basic impulse insulation level of not less than 75 kV.

The IEC relaying accuracy class at 50-Hz shall be at least 3P for protective circuits and class 1.0 for measuring or metering circuits.

All secondary leads shall be brought out to the generator terminal cabinet and terminated on clearly marked 600 V fused terminal blocks.

2.4.5.6 Earthing Transformers

Use existing grounding transformer and resistor.

Generator shall be provided with a suitable grounding transformer and resistor. The primary rated voltage of the transformer shall be at least 1.3 times the line voltage of the generator. The resistor and transformer shall be designed with an impedance to match three times the capacitive impedance of the generator circuit including the generator cables and transformer. The generator earths and the generator neutral earthing transformer shall all be tied to a common station earthmat. The grounding transformer and resistor shall be suitable for outdoor mounting and shall be enclosed to prevent harm to personnel. The grounding transformers shall be located on the machine floor level.

2.4.5.7 Bearing Temperature Sensors

Resistance temperature detectors (RTDs) shall be dual platinum, 100 ± 0.1 Ω at 0°C type.

Each RTD shall be connected by 3 leads to terminal blocks located in the generator terminal box. One wire from each detector shall be connected to a common point or bar on the terminal block. The common point for the bearing temperature detectors shall be separate from that for the stator winding temperature detectors. The common points shall be insulated from ground, but provisions shall be made for a grounding connection on or near each terminal block. All wiring between the terminals and the individual temperature detectors shall be furnished and installed.

2.4.5.8 Vibration Sensors

Each of the generator bearings shall be fitted with two axis vibration monitoring. The monitors shall have one 4-20 mA analogue signal output per axis connected to the Unit PLC. All of the vibration monitor interfaces shall be wired to the Generator junction box.

Vibration Monitoring pickup heads shall be located in close proximity to the bearing and must monitor movement in the direct vicinity of the bearing. If necessary sensors with pickups remote from the transmitter shall be used.

2.4.5.9 Bearing Pads

Replacement bearing pads shall be white metal babbitt type supplied by the original generator or bearing manufacturer.
Bearings shall be capable of operating continuously, without injury, with the machine rotating at any speed from 50% to 120% of rated speed.
The bearing metal temperature shall not exceed 70°C under continuous operation of the turbine generator at any load between zero and rated full load.

2.4.5.10 Lubrication Oil Systems

For bearings requiring pumped oil lubrication the following minimum requirements shall be met:-
An oil lubricating system shall be furnished to provide oil to the bearings. The oil lubricating system shall include one main and one backup, full-capacity, oil pumps.

The main pump shall be direct-connected to a 415 Volts 3-phase AC, low-starting-current, induction type motor, designed for full-voltage direct on line starting. The backup pump shall be direct connected to a 110V DC motor.

All controls, motor starters, instrumentation, gauges, valves, filters, regulators, and protective devices shall be included to provide a fully automatic system in which the backup pump starts immediately under any of the following events:-

- The main pump fails to maintain lubrication oil pressure.
- The main pump thermal overload protection operates.
- The 400V supply to the main pump fails
- A turbine generator overspeed event occurs.
- A bearing oil temperature alarm is raised by the Unit PLC.
- The Unit PLC fails.

The lubrication oil system shall be provided with a sump tank which shall form the base for the oil pumps or other suitable arrangement subject to approval of the Project Manager. The capacity of the sump tank shall not be less than 1.2 times that required to contain all of the working oil that can be discharged back into the sump by completely discharging lubrication oil system.

The sump tank capacity shall be sufficient to maintain the oil level within an adequate working height during operation. The sump tank shall be provided with suitable access openings and with a fine mesh screen strainer or individual pump suction strainers through which all oil pumped shall pass.

The strainer or strainers shall be readily removable for cleaning without draining the sump tank. The sump tank shall be equipped with a flush-mounted oil-level indicator, a filler connection, a drain connection with oil drain valve, and connections for circulating the oil through an oil purifier. Oil level switches shall be also provided for high and low level alarms and shut down of the oil pumps on very low oil level.

The sump tank shall be equipped with tank breathers. Breathers shall have a filtration rating equal to or better than the oil purification system filter. Exhaust from breathers shall be free from oil mist.

The pump sets shall include pressure relief valve, simplex filter and lockable multi-turn flow control valves to allow precise control of oil flow to each bearing.

Where required an oil-to-water heat exchanger of material suitable for the water quality shall be provided, including inlet filters.

The lubrication oil system shall include, but not be limited to, the following instruments:

- One pressure switch, pressure gauge, filter, and check valve at the discharge piping of each pump.
- One flow indicating switch, pressure switch, pressure surge limiter (to avoid pulsations), pressure relief device, and pressure gauge in the common supply header from the 2 pumps.
- Lube oil sump oil level low trip, low alarm and high alarm switches.
- Lube oil temperature RTD.

The Contractor shall supply a first fill of all lubricating oil.

2.4.5.11 Cooling Water Systems

Not applicable. Same turbine and cooling system is reused.

For turbine generators requiring cooling water the following minimum requirements shall be met:-

The cooling water shall be taken from the turbine inlet pipework, downstream of the inlet valve.

All cooling water pipework shall be 316L stainless steel.

The cooling water system capacity and pressure requirements shall be determined based on cooling water flow rates and pressures required by the supplied items. The Contractor shall add appropriate design margins to the capacity and pressure requirements.

The cooling water system shall be designed based on the maximum river water temperature.

Duty and standby 0.1mm mesh strainers shall be provided, with isolating valves to allow maintenance without stopping the system.

A valve, with 110V DC operated actuator, shall be provided for isolating the cooling water supply when the turbine generator is shut down.

The cooling water system shall include, but not be limited to, the following instruments downstream of the cooling water isolating valve and interfaced to the Unit PLC:

- One pressure switch
- One flow indicating switch (thermal type)

- Cooling water temperature RTD.
- Strainer differential pressure (one per strainer)

2.4.5.12 Brakes

Use existing.

For turbine generators requiring brakes the following shall apply:-

The brakes shall be hydraulic oil operated using oil from the governor hydraulic power unit. The brakes shall act on the generator flywheel and shall bring the generator and turbine, under normal operating conditions, to a stop from 50% rated speed within 5 minutes after the brakes are applied.

A valve, with 110V DC operated solenoid, shall be provided for initiating brake operation.

Brake pads shall be asbestos free and shall be such that galling of the generator flywheel will not occur during braking.

The braking system shall include, but not be limited to, the following instruments interfaced to the Unit PLC:

- One pressure switch downstream of the brake control valve.
- One limit switch to for brake "on" indication.
- One limit switch to for brake "off" indication.

2.4.5.13 Inlet Valve Actuators

For turbine generators requiring inlet valve actuators, the following shall apply:-

2.4.5.13.1 Valves with Quarter Turn Actuation

Where the turbine inlet valve has a quarter turn actuator (eg butterfly or spherical type), the actuator shall be a linear hydraulic servomotor operated using hydraulic oil from the turbine governor. Where practicable, the valve shall be closed using a gravity counterweight and opened using oil pressure. Where this is not possible, hydraulic pressure shall be used to both open and close the valve.

The hydraulic servomotor assembly shall include a cylinder tube, cylinder heads, piston, piston rod, seals, accessories and appurtenances. Design shall be such that hydraulic oil is present on both sides of the piston to prevent corrosion.

Hydraulic cylinder assemblies shall be designed so that, when the valve and operator assembly are erected exactly to the nominal design geometry, the piston rod shall not have any available overstroke for complete rod extension when the valve is fully open (stops shall be provided to limit the valve disc travel at the full-opened and full-closed positions).

The cylinder rod shall be hard-chromium-plated with a minimum plating thickness of 0.075 mm after machining. The chrome plating shall be performed in at least 2 stages. The thickness for each stage shall not exceed 0.05 mm.

The cylinder shall have a permanently mounted speed limiting orifice at the part of the rod end chamber, installed either on the cylinder tube or on the rod end head, close to the pressure line connection. This orifice shall limit the closing speed of the valve in case of a rupture in the connecting pipes.

The cylinder design shall

Each cylinder shall be equipped with proximity switches to indicate to the Unit PLC:-

- Valve fully closed
- Valve full open
- Valve 10% open

Piping from the governor HPU to the valve actuator shall be in 316L stainless steel, with flexible hydraulic hose for the final connections.

2.4.5.13.2Valves with Multi-Turn Actuation

Use existing.

Where the turbine inlet valve has a multi-turn actuator (eg slide type), the actuator shall be either:-

i. A rotary hydraulic servomotor operated using hydraulic oil from the turbine governor. Or
ii. A 400V AC actuator with battery, or other form of stored energy, backup to ensure that the valve can be closed even if the AC local service power fails.

If a rotary hydraulic servomotor is used, then the governor accumulator shall be sized to operated the servomotor for two close and one open cycle, in addition to the capacity required for other governor functions. Piping from the governor HPU to the valve actuator shall be in 316L stainless steel, with flexible hydraulic hose for the final connections.

2.4.5.14 Turbine Spear Valve/Deflector or Wicket Gate Actuators.

For turbine generators requiring upgraded Turbine Spear Valve/Deflector or Wicket Gate Actuators, the following shall apply:-

The hydraulic servomotor assembly shall include a cylinder tube, cylinder heads, piston, piston rod, seals, accessories and appurtenances. Design shall be such that hydraulic oil is present on both sides of the piston to prevent corrosion.

Hydraulic cylinder assemblies shall be designed so that, when the valve and operator assembly are erected exactly to the nominal design geometry, the piston rod shall not have any available

overstroke for complete rod extension when the spear valve/deflector/wicket gates are fully open. The assemblies shall be designed with a slight over travel in the closing direction to apply a squeezing force on the closed spear valves/wicket gates. Mechanical stops shall be provided to limit travel at the full-opened and full-closed positions.

The cylinder rod shall be hard-chromium-plated with a minimum plating thickness of 0.075 mm after machining. The chrome plating shall be performed in at least 2 stages. The thickness for each stage shall not exceed 0.05 mm.

The cylinder shall have a permanently mounted speed limiting orifice at the part of the rod end chamber, installed either on the cylinder tube or on the rod end head, close to the pressure line connection. This orifice shall limit the closing speed of the spear valve/wicket gate in case of a rupture in the connecting pipes.

Each cylinder shall be equipped with proximity switches to indicate to the Unit PLC:-

- Valve fully closed
- Valve full open
- Valve 10% open

Piping from the governor HPU to the valve actuator shall be in 316L stainless steel, with flexible hydraulic hose for the final connections.

2.4.6 Generator Step-Up Transformers

2.4.6.1 Type and Description

Each generator step-up transformer shall be an outdoor, oil-immersed three phase, double-wound type unit based in a single tank having directed flow design incorporating directed flow washers within the winding with the bulk oil being directed through the winding.

The transformer shall conform to the requirements of IEC 60076 and be suitable for operation under IEC 60354. The transformers shall each meet continuous rated power with ONAN cooling.

Number of phases	3
Cooling	ONAN
Frequency, Hz	50
Number of windings	2
Primary winding, rated V	22,000
Secondary winding, rated V	6,600
Primary connection	Wye
Secondary connection	Delta
Winding Vector Group	Ynd11
Minimum impedance from high voltage to low-voltage winding, based on rated kVA (%)	6.5%

Primary winding taps for rated kVA on-load taps; low rated voltage	+5.0% to -5% in 2.5% steps
Average sound pressure level, dBA	65
Winding temperature rise, above a 24-hr average 25°C ambient, with a maximum ambient of 40°C	80°C
Power Frequency Withstand Primary/Secondary windings	50kV/22kV
Basic Insulation Level Primary/Secondary Windings	125kV/60kV

2.4.6.2 General Design Requirements

Each transformer shall preferably be of the hermetically sealed type.

Each transformer shall be suitable for mounting on a concrete pad. Both the transformer and any separate radiator banks will be mounted on the same pad. The transformer feet will be directly bolted to the pad. The feet shall be sized such that the bearing pressure shall not exceed 2 MPa. The hole drilling arrangement shall be to the Project Manager's approval.

Anti-vibration padding shall be provided under the transformer feet. The feet shall be sized to not exceed the recommended bearing pressure of the padding.

2.4.6.3 Core

The core shall be constructed of the highest quality steel especially suitable for the purpose. The steel shall be in thin laminations, annealed after cutting, and rolled to ensure a smooth surface at the edges. Both sides of each sheet shall be insulated with a durable, heat-resistant, baked enamel or varnish. The cores shall be carefully assembled and rigidly clamped to ensure adequate mechanical strength to support the windings.

2.4.6.4 Windings

Both primary and secondary windings shall be vacuum pressure impregnated. Each coil shall be cast under vacuum to ensure complete and void-free resin impregnation throughout the entire insulation system.

Transformer windings shall be copper. Transformer connections shall be made using insulated copper bus and bus supports.

2.4.6.5 Enclosures

The transformer shall be provided with an oil-tight galvanized steel case. The joints between the case and cover shall be such that the cover and top section of the case are integral. Gasket or shield material, which will not deteriorate under service conditions, shall be provided between the top cover and case. The top cover shall be bolted to the case.

The transformer shall be provided with eyebolts and/or lugs for lifting the essential parts and for lifting the completely assembled transformer filled with oil. Guides shall be provided inside the case for guiding the cores and windings as they are being removed from or lowered into the case.

The transformer case shall be provided with a pressure relief diaphragm or valve of adequate size to protect the case against a primary explosion due to arcing below the surface of the oil. The relief diaphragm shall be designed so as to minimize discharge of oil and to exclude air and water after it opens. It shall be equipped with a visual alarm indicator and with alarm contacts.

The transformer case shall be capable of withstanding without leakage or distortion a full vacuum and an internal gas pressure 25% greater than the maximum operating pressure resulting from the system of oil preservation used. All valves, fittings, and piping affected by this requirement shall be of correct design and construction for full vacuum filling.

The transformer shall be provided with approved valves as required for:

- Draining the case (flanged-gate valve).
- Sampling oil from the extreme bottom of the case.
- Sampling oil from the top of the case.
- Filling the case and radiators.
- Conservator.
- Isolation of Buchholz relay.

Oil valves shall be specially designed for use with insulating oil and shall hold hot oil without leaking. An air vent shall be provided on the transformer at the top of the case and piped to a valve within reach from the floor for releasing air when the case is being filled with oil and/or nitrogen gas.
Two transformer tank grounding pads shall be furnished on opposite sides of the tank near the transformer base.

2.4.6.6 Conservator Tank

Where required, the generator transformer may be fitted with separate overhead conservator tanks. These shall be formed of substantial steel plates and arranged above the highest point of the oil circulating system.

The conservator for the main tank shall be of the fully sealed type to prevent the ingress of oxygen, moisture, and particles into the transformer oil. It shall consist of:-

- An impermeable synthetic rubber membrane which separates the oil from the air. This may be either a diaphragm or cell.
- Breather connected to the air side of the rubber membrane.
- Sump (for connection of oil sampling connection).
- Oil level gauge with alarm contacts to indicate the oil level at the bottom of the rubber membrane.
- Air release valve - to permit bleeding off air during filling of the transformer or when in service.
- Oil handling facilities as detailed in this specification.

- Inspection covers to permit inspection of the rubber membrane without dismantling the conservator.

The internal surfaces of the conservator shall be treated to resist corrosion. The design of the conservator shall be such that internal repainting (of the conservator) and the replacement of the rubber membrane can be easily carried out.

The conservators shall have sufficient capacity to accommodate expansion and Contraction of the oil due to temperature changes from -10^{o}C to 100^{o}C.

The conservator tank shall be tested for leaks in the same manner as the main tank.

Each transformer shall be provided with a separate dehydrating breather for each air space above insulating oil surfaces, and the airside of the rubber membrane of the main tank conservator.

Breathers of the silica gel type shall be suitably coloured to indicate when they are saturated with water and require treatment. The silica gel shall be able to be viewed without any dismantling. Air entering any conservator must pass through the breather but the external atmosphere shall not be in contact with the silica gel when breathing is not occurring. Not less than 1 kg of silica gel shall be provided in a breather per 3000 litres of oil protected. Each removable element shall weigh not more than 20 kg.

2.4.6.7 Tap Changer

The transformer shall be equipped with an externally, manually-operated no load tap changer rated for the maximum rating of the transformer and suitable for changing connections to the taps in the windings. Taps shall be changed only when the transformer is de-energized. The operating hand wheel shall be mounted on the side of the case at a convenient height for operating from the floor on which the apparatus is mounted and shall include an indicating pointer and dial and means for locking the tap changer in any desired position.

2.4.6.8 Insulating Oil

Insulating oil used for oil impregnation and testing at the Contractor's works shall be PCB free, uninhibited and free of all additives.

Oil used for filling on site will be supplied under this Contract and will be inhibited oil to Class 1A of BS 148.

2.4.6.9 Cooling System

Cooling shall be ONAN.

Where external radiators are required, they shall be of the panel type and shall have the following features:-

- Externally galvanised
- Drain valve
- Air admission vent
- Two lifting lugs per radiator
- Isolating valves to permit uncoupling from the radiator bank without draining the bank. These valves shall withstand full vacuum.

- Bracing lugs. Radiators shall be adequately braced to withstand the seismic forces detailed in this specification.
- No crevices where moisture may be trapped and thereby cause corrosion
- A bolted earth bond to the support structure

Radiators shall be tested for leaks by the same methods as used for the transformer tank, and shall withstand full vacuum.

Any radiator shall be able to be removed from a bank without first removing any other item such as conservator or other radiators.

2.4.6.10 Bushings & Terminals

The HV and LV winding connections of each transformer shall be brought out through the transformer tank wall by means of outdoor bushings in a cable box.

Cable boxes shall be air insulated and located with the bottom of the box located at a sufficient level above the bottom of the transformer tank to permit power cable access.

Each cable box shall be provided with two earth terminals per phase for the following purposes:-
- The separate earthing of the copper wire screen of each cable.
- The temporary earthing of the cable terminal.
- The temporary earthing of the bushing terminal.

Each cable box shall have a removable gland plate made of non-magnetic metal.
Where proprietary plug and socket arrangements are used for HV terminations, the cable termination kit shall be supplied.

2.4.6.11 Earthing Terminals

Earthing terminals complying with this specification shall be provided. Two shall be located on the transformer tank, one on either side and near to ground level, and one on any separate associated radiator bank, to facilitate connection to the local earthing system. The earthing terminals shall be sized for connecting 150 mm2 cable clamps

2.4.6.12 Control, Instrumentation & Protection

The following control, instrumentation and protection features shall be provided:-

2.4.6.12.1 Oil Temperature Indicator

The main tank of each transformer shall be provided with a dial type oil thermometer with range of not less than 20oC to 120oC over a scale length not less than 110 mm, a resettable maximum indicator pointer, and an alarm contact adjustable between 60°C and 90°C. The thermometer shall indicate the temperature to + 2°C. A digital alternative may be offered. In addition, a temperature transmitter having 4-20 mA dc analogue output shall be provided. The oil temperature indication devices shall be wired to the Unit Control and Protection Panel.

2.4.6.12.2Winding Hot Spot Monitor

The transformer shall be provided with winding hot-spot monitoring consisting of a current transformer, thermal replica device, winding temperature indicator and relay contacts.
If the highest hot-spot temperature can be in more than one winding, depending on load or tap position, then the above separate monitoring shall be provided for each winding in which the hot-spot can occur.

The windings of CTs supplying the thermal replica device shall be protected against open circuit overvoltages.

Each winding temperature relay shall have four or more independent contacts, two of which shall be control contacts which shall be separately adjustable over a range of at least 70°C to 90°C, and two of which shall be separately adjustable alarm contacts with a range of at least 60°C to 150°C.

The winding temperature indicators shall have a range of at least 20°C to 150°C over a scale length of 110 mm. The indicated temperature shall be able to be easily read by a person standing at the base of the transformer. A digital alternative may be offered. For each winding temperature indicator a temperature transmitter having self powered 4-20 mA dc analogue output shall be connected to the Unit PLC.

2.4.6.12.3 Oil Level Indicators

For all transformers fitted with a conservator tank, an oil level indicator shall be supplied for the conservator tank. This indicator shall be clearly visible to an observer on the ground, and shall have contacts for high and low level. The contacts shall be wired to the Unit PLC.

Dial type magnetic oil level indicators shall be used, not prismatic type. The minimum indicated oil level shall be with the connection pipes to the conservator covered with not less than 10 mm depth of oil. The indicated range of oil levels shall correspond to average oil temperatures of - 10°C to 80°C. The correct oil level at 15°C, 35°C, 55°C and 75°C shall be marked on the gauge. A separate plate giving temperature/gradation equivalence is not acceptable.

2.4.6.12.4 Gas and Oil Operated Relays

The connection pipe between the conservator tank and the transformer main tank shall be fitted with a gas operated (Buchholz) relay for the protection of the transformer. The connection pipe shall have the same bore as the relay.

A stop valve shall be provided on the conservator side of the Buchholz relay. The stop valve shall have clearly marked `open' and `closed' positions that are visible from ground level. A means of securing the valve in the `open' position is required, preferably without the use of key locking devices.

The construction of the transformers shall be such that all rising gas will readily reach the Buchholz relay(s), piping being provided if necessary to lead away gas or air trapped in any pockets in the top of all separate bushing turrets/compartments.
The Buchholz relays shall be provided with both "Trip" and "Alarm" contacts wired to the Unit Control and Protection Panel.

Piping and petcocks shall be provided so that gas and air can be released from the Buchholz relays and air can be injected into the top and bottom of these relays to test the operation of the contacts. The required pressure of the air injected through the bottom connection to test the trip contact shall not exceed 2,000 mbar. The piping shall be at least 6 mm inside diameter.

2.4.6.12.5 Pressure Release Device

For all transformers fitted with a pressure release device, the device shall be fitted with visual indication and remote monitoring of its operation. This indicator shall be clearly visible to an observer on the ground, and shall have contacts for high and low level. The contacts shall be wired to the Unit Control and Protection Panel.

2.4.7 Control and Instrumentation Systems

2.4.7.1 Type and Description

A control and instrumentation system shall be provided to control and monitor the generating unit and all the power plant apparatus.
The control system shall be designed to allow the scheme to operate in a fully automatic manner with limited Operator involvement. The powerhouse will normally be monitored and controlled from the Employers National Control Centre (NCC) located at Fuluasou Substation. The power scheme controls and protection systems must be designed to:-

a) Ensure the safety of the Facilities, EPC staff and the general public during normal and abnormal event.
b) Maximise the efficient utilization of water of the controlled scheme.
c) Minimise the lost generation following plant trips and other disturbances.
d) Alert the EPC Operator to any abnormal condition that may exist with the Facilities and of any maintenance that may be required.

The scope of supply, work and services shall be complete in every respect for the purpose it is intended, even if it is not explicitly stated in these technical Employer's Requirements.

The Plant and Facilities will be monitored and controlled locally via the operator's stations and HMI's and remotely at the Employer's NCC.

2.4.7.2 Controlled Equipment

For turbine generator and transformer Unit:

a) Turbine and speed governor.
b) Generator and excitation system.
c) Unit Transformer.
d) Unit 22kV Switchgear
e) Cooling water equipment.
f) All unit auxiliary systems and equipment.

General services of the powerstation:

a) Station service AC and DC systems.
b) Powerhouse drainage and dewatering systems
c) Powerhouse ventilation
d) Penstock isolating valve.
e) Powerhouse compressed air systems

2.4.7.3 Control System Operation

2.4.7.3.1 General Requirements

The control system shall provide centralized control and monitoring of the power plant from an operator station located in the control room of the powerhouse or from the Employers NCC.

The control system shall be configured to provide the following functions:

a) Manual and automatic starting and stopping of the generating unit.

b) Control of MW and MVAR output of the generating units.
c) Monitor and log the status of generating units.
d) Monitor and control the station services, generating unit auxiliaries, penstock intake gates, headpond water levels, water cooling systems, and other powerhouse systems hereinafter specified.

Features of the control system shall include:

a) Alarm annunciation and management
b) Data acquisition and control.
c) Human Machine Interface (HMI)
d) Historical data management
e) Integration with the EPC NCC

The control system shall be programmable logic controller ('PLC' – as per IEC 61131) based with PC based HMI workstations, providing a completely integrated state-of-the-art system. The system shall have an "open architecture" which shall permit reconfiguration, expansion, and future upgrade.

The control system at powerhouse shall include as a minimum the following equipment:

a) One HMI Operator's Station located in the powerhouse control room.
b) One "Unit" PLC per turbine generator used for control and monitoring of the associated turbine generator.
c) One "Station" PLC for control and monitoring of the power station, remote Penstock Valve and dam level.
d) One fault-tolerant, redundant, fibre optic based 100MBPs Ethernet LAN serving all of the equipment listed above.
e) Other hardware and software required to fulfil the requirements of these Employer's Requirements.

2.4.7.3.2 Design and Performance Criteria

The control system shall be designed to minimize the duration of failures by the ability to diagnose and resolve problems quickly and to replace any failed part easily.

The Average System Availability over a one year period shall be 99.8% or better. The Contractor shall provide a guarantee for the Average System Availability with his Tender.

The hardware and software elements of the Control system shall be easy to maintain using the maintenance facilities, hardware and software tools, and recommended spare parts provided by the Contractor.

All tuning parameters and setpoints shall be accessible by the Employer, via password protected engineering screens on the HMI system.

The PLC code shall be provided to the Employer, along with a licensed copy of the programming software installed onto a Notebook computer. The PLC code must be fully open to the Employer with no 'locked' elements.

2.4.7.3.3 Expandability

The Control system shall be capable of being expanded over and above the specified system by adding more stations, PLCs, functions, input-output modules, or metering modules. This expansion shall not degrade the performance of the existing system. Twenty (20) percent spare capacity is to be provided.
For ease and flexibility in expanding the Control system, the Contractor shall conform to the open architecture concept as described herein.

2.4.7.3.4 Product Quality and Advanced Technology

The Employer requires hardware and software products of high quality in design, fabrication, and performance.

The standard hardware equipment (such as printers, etc) and devices of the control system shall be brand-new and shall be as close as possible to being of the latest design technology. In order to meet this requirement, the Contractor shall defer the procurement of all standard hardware as late as possible in the project schedule until just prior to system integration. Similarly, for the standard software, the latest versions available at time of Factory Acceptance Test (FAT) shall be delivered.

The Contractor shall use and provide the latest versions of all the standard software, e.g., the operating system, utilities, language compilers, graphics software, picture editor, networking software, database management system, which are available at the time of system integration, as long as there is full upward compatibility with the control system software. PLC programming must comply with IEC 61131-3.
All software shall be standard. Therefore, any Contractor's code modification on standard software packages shall not be permitted.

All software shall use the Microsoft Windows 7 Operating System. All software shall be in the English language.

The control system PLC hardware and software must be from a recognised global supplier of such equipment. Spare parts and engineering support for the PLC hardware and software must be available to the Employer from licensed representative companies located either in Samoa, or in countries with regular (at least bi-weekly) direct flights to Apia.

2.4.7.4 Unit Controllers

2.4.7.4.1 General Requirements

a) Unit Controllers (Unit PLC) shall be PLC based, and shall include main and auxiliary memory, HMI with keyboard/pad and optical mouse, interfaces with intelligent devices and Process LAN interface. One Unit PLC shall be provided for each turbine generator.

b) The Unit PLC shall be a standalone system, designed to operate totally independent from other devices in the Control system. Therefore, all functions shall be available in the Unit PLC at all times, regardless of whether the Process LAN is in service or not.
c) The Unit PLC shall be located in a Unit control panel near the generator on the generator floor.
d) The Unit PLC shall communicate with multifunction meter modules, and protection relays using Modbus or DNP3 communication protocols.
e) The Unit PLC shall communicate with other drops in the system over the Process LAN, using industry-standard communication protocol based on TCP/IP.
f) The Unit PLC functions shall be programmed in an IEC61131-3 compliant language.

2.4.7.4.2 Control Functions

The Unit PLCs shall have the necessary processing power, memory, software, and peripheral facilities to perform the following functions:

- Control of unit start up.
- Control of unit shut down.
- Turbine speed and load governing.
- Monitoring of turbine generator unit pressures, levels, vibrations, flows, temperatures etc and providing protection system "trips".
- Monitoring of hardwired trips from protective relaying system and providing backup 'trips'.
- Individual control of generating Unit MW and MVAr setpoints.
- Control of auxiliary equipment including pumps.
- Control of unit 22kV circuit breaker (synchronised closing will be via synchroniser).
- Unit alarms.

Note that the Unit designs shall be based on the premise that the Unit PLC must be in service for the generating unit to operate.

2.4.7.4.3 Individual Control of MW Generation

The Unit PLC shall have the software for executing MW setpoint controls entered manually by the operator at any of the operator stations or HMIs. The setpoint control software shall be a closed loop, proportional-integral controller of the generator MW output.

The setpoint control algorithm shall always operate with the last setpoint value received by the Unit PLC.

The setpoint value stored at the Unit PLC shall be replaced only when a new value is received.

2.4.7.4.4 Individual Control of MVAR Generation

The Unit PLCs shall have the software for executing MVAR setpoint manually entered by the operator at any of the operator stations or HMIs. The setpoint control software shall be a closed loop, proportional-integral controller of the generator MVAR output.

The setpoint control algorithm shall respect the maximum and minimum reactive power limits of the generating unit that shall be calculated dynamically in the Unit PLC. Reactive power limits shall be calculated using the generator capability curves. These limits shall be modifiable by the Operator on the HMI.

The setpoint control algorithm shall always operate with the last setpoint value received by the Unit PLC.

The setpoint value stored at the Unit PLC shall be replaced only when a new value is received.

2.4.7.4.5 Automatic Start Sequence Control

The generating unit automatic start sequence shall be initiated by an operator's request at any of the HMIs.

A sequential control algorithm resident in the Unit PLC shall execute the automatic start sequence. The Contractor shall define the exact sequence, pre-start conditions, and timers.

The automatic starting sequence program shall control the turbine-generator unit through a series of steps from one steady state to another, starting with the unit at dead stop and ending with the unit synchronized to the power system and with load.

The Unit PLC shall perform as a minimum the following sequence within a predetermined time schedule:

a) Pre-start conditions and permissives satisfied.
b) Penstock at pressure and penstock isolating valve open
c) Unit Auxiliaries start.
d) Governor start.
e) Unit spinning up.
f) Excitation on at 95% speed.
g) Unit auto synchronizer activated at greater or equal to 95% speed.
h) Unit synchronized on-line.
i) Unit loaded to minimum load.

The Unit PLC shall notify the operator of any discrepancy of unit status with the expected normal operation at all stages of the starting sequence. Failure to complete the sequence will result in the unit being automatically shut down.

The operator shall have the option of interrupting the starting sequence at any steady state. After the operator interrupts the automatic sequence, the Unit PLC control logic shall be designed to return to the last steady state.

2.4.7.4.6 Automatic Stop Sequence Control

The generating unit automatic stop sequence shall be initiated by an operator's request at any of the HMIs.

A sequential control algorithm resident in the Unit PLC shall execute the automatic stop sequence. The Contractor shall define the exact sequences, pre-stop conditions, and timers.

The automatic stopping sequence program shall control the turbine-generator unit through a series of steps from one steady state to another, starting with the unit loaded and ending at dead stop.

The Unit PLC shall perform as a minimum the following sequence within a predetermined time schedule:

a) Pre-stop conditions.
b) Load condition reduced to minimum operational load.
c) Unit circuit breaker trips.
d) Excitation off.
e) Spear valve/wicket gate closed.
f) Speed reduction.
g) Brakes on.
h) Zero speed.
i) Inlet valve closed
j) Dead stop condition.

The Unit PLC shall notify the operator of any discrepancy of unit status with the expected normal operation at any stage of the unit stopping sequence. Failure to meet the stop sequence will result in a unit trip being initiated.

The operator shall have the option of interrupting the stopping sequence at any steady state. After the operator interrupts the automatic sequence, the Unit PLC control logic shall be designed to return to the last steady state. A Unit restart shall be possible from any of the steady states.

2.4.7.4.7 Turbine Generator Protective Functions.

The Unit PLC shall monitor the mechanical behaviour of the turbine generator unit and trip the unit in the event of abnormal condition detection.

The PLC shall have outputs wired directly into the turbine generator shutdown circuits for this purpose. In addition, the Unit PLC shall have a watchdog contact that will trip the turbine generator in the event of a PLC failure.

Further details of the protective functions to be provided by the Unit PLC are described in Part 2.4.9 Protective Relaying System.

2.4.7.4.8 Synchronising

The Unit Control Panel shall include an automatic synchroniser configured to operate into the 22kV generator circuit breaker. Provision for manual synchronising shall also be provided at the Unit Control Panel.

2.4.7.5 Station PLC

2.4.7.5.1 General Requirements

a) For stations with two or more turbine generators a Station PLC shall be provided.
b) The Station PLC shall be PLC based, and shall include main and auxiliary memory, HMI with keyboard/pad and optical mouse, interfaces with intelligent devices and Process LAN interface.
c) The Station PLC will be located in the Station Services control panel located on the generator floor.
d) The Station PLC shall communicate with input-output modules, multifunction meter modules, and protection relays using Modbus or DNP3 communication protocols. All components shall be seamlessly integrated in the Control system.
e) The Station PLC shall communicate with other drops in the system over the Process LAN, using industry-standard communication protocol based on TCP/IP.
f) All Station PLC functions shall be programmed in an IEC61131-3 compliant language.

Where the station has a single turbine generator, the following requirements shall apply to the Unit PLC.

2.4.7.5.2 Control Functions

Where the station has a single turbine generator, the following requirements shall apply to the Unit PLC.

The Station PLC shall have the necessary processing power, memory, software, and peripheral facilities to perform the following functions:

- Turbine generator start/stop scheduling (via Unit PLC)
- Penstock valve close control and monitoring
- Headpond level control and monitoring.
- Penstock intake screen differential pressure monitoring.
- Local Service AC System control and monitoring.
- DC Systems monitoring
- Powerhouse sump pumps control and monitoring
- Powerhouse dewatering pumps control and monitoring.
- Fire alarms monitoring.
- Security Systems monitoring.
- Interfacing with Employers SCADA

The power station Operator shall have the ability to set a joint MW output of all operating turbine generators to a set point and the Station PLC will automatically load the turbines to achieve that output.
The Operator shall also have the ability to select joint level control. Under this mode the Station PLC will automatically load and unload the operating turbine generators to maintain the headpond at a constant level.

Under both operating modes, the Station PLC shall have the ability to automatically start and stop "available" turbine generators to prevent the headpond from being excessively drawn down, or from spilling water. The Operator shall have the ability to turn this overriding control on or off.

2.4.7.5.3 Station Service Routines

The station service monitoring routine shall be designed to give alarm and operating messages to the operator for all possible fault conditions in the operation of the station service systems.

2.4.7.5.4 Employers SCADA Interface

The Station PLC shall be used as a data concentrator for interfacing the Plant control and instrumentation system, including the protection relays, with the Employers NCC SCADA system.

The Station PLC shall be interfaced to the SCADA by means of a DNP3.0 communications port from the Station PLC to the SCADA

2.4.7.6 PLC Technical Requirements

2.4.7.6.1 General

Each PLC shall be provided with a system of input-output modules (local or remote), instrumentation bus, and power supplies.

The input-output modules and power supplies shall meet the Surge Withstand Capability standards as defined by IEC or ANSI/IEEE.

2.4.7.6.2 Processors

Processors shall support standard IEC 61131-3 languages. As a minimum these are to include the following:

- Ladder Logic.
- Sequential Function chart.
- Function Block Diagram.
- Structured Text.

The processors shall have sufficient internal memory to run the PLC program without the need for external memory cards. Processors shall be supplied with enough surplus memory to allow future modifications to the program.

All processors shall have either non volatile memory or be supplied with internal batteries to prevent loss of volatile memory.

The processors must have facility for online changes to be made to the program code.

2.4.7.6.3 Digital Input Modules

Digital input modules shall accept normally open or normally closed dry contacts for status and sequence-of-events inputs. All digital inputs shall include optical isolators and filtering to eliminate contact bounce.

The digital input module shall accept bi-stable and momentary-change inputs. Circuit breaker status and switch positions are bi-stable inputs. Equipment alarms and protective relay operations are momentary-change inputs.

Protective relay operations, including electrical and mechanical protective devices, shall be processed as Sequence-of-Event (SOE) inputs. SOE inputs are momentary-change inputs that shall be detected within the resolution window specified for SOE recording.

Digital input modules shall use 110V-DC as the signal voltage.

No more than 16 IO points are permitted on any single digital input Module. The maximum number of IO points with common 0V rail shall be 8.

2.4.7.6.4 Analogue Input Modules

The analogue input modules shall accept and process transducer voltage signals in the range of ± 10-V DC or current signals in the range of ±20 mA DC. All inputs shall be optically isolated.

The analogue input processing shall include filtering, scaling, and A/D conversion with a 12-bit 2's complement resolution.

Accuracy shall be at least ±0.05% and linearity ±2 LSB over the full input range and temperature range.

2.4.7.6.5 Resistance Temperature Detector (RTD) Input Modules

The RTD input modules shall have the capability of interfacing with Platinum RTDs.

All RTD inputs shall be wired to RTD input modules on the PLCs. Multiplexing of RTD signals is not permitted.

The RTD input module shall have a resolution of 0.1°C, accuracy of 0.8°C for RTD Type 100-Ohm Platinum.

2.4.7.6.6 Control Output Modules

The control outputs shall be of the “clean contact”, individually isolated type, with each output individually configurable as normally open or normally closed.

Control Output modules shall use 110V-DC as the signal voltage.

No more than 16 IO points are permitted on any single control output module.

2.4.7.6.7 Analogue Output Modules

The analogue output modules shall transmit process control signals in the range of ± 10-V DC or current signals in the range of ±20 mA DC. All outputs shall be optically isolated. Outputs shall revert to 0V DC or 0mA DC in the event of a module failure.

The analogue output processing shall include filtering, scaling, and A/D conversion with a 12-bit 2's complement resolution.

Accuracy shall be at least ±0.05% and linearity ±2 LSB over the full input range and temperature range.

2.4.7.6.8 Communications Media

The communications media for external (outside PLC cabinet) communication links shall be fibre optics.

The communications media for internal (inside PLC cabinet) communication links and short links between adjacent cabinets may be copper but shall be to the Project Manager's approval.

2.4.7.6.9 Physical Requirements

The PLCs shall be housed in a standard electronic equipment cabinet with a window door.

2.4.7.6.10 Power Requirements

The PLCs shall be suitable for operation from 110V-DC. All control and indication wiring to and from the PLC panels shall be 110V-DC and 240V-AC wiring is strictly prohibited.

2.4.7.6.11 Configuration System

The PLCs shall be provided with a Windows-based configuration system, which shall include all the necessary software to configure and program any function in the PLC.

The configuration system shall be installed on the portable maintenance PC.

The configuration system shall allow downloading and uploading of configuration data files.

The configuration system shall program, download, debug and store programmable algorithms.

The Contractor shall ensure that **all** OEM licenses for the configuration system are valid throughout the warranty period. The configuration software must have an international license and there shall be no requirement for hardware 'dongle' type security devices.

The Operating system shall be Microsoft Windows 7.

2.4.7.6.12 Programming Language

The programming package shall be an industry standard package IEC 61131-3 compliant and shall be totally integrated with the PLC software. No special database shall be required for the implementation of control programs. The control programs shall use ladder diagrams; function

block diagrams, sequential function charts, structured text, instruction lists, and C++ based routines. Programs shall be fully annotated with tags and comments on a per line basis to fully document the code functionality. The programming package shall support on-line and off-line development, off-line simulation, documentation and reporting capabilities.

2.4.7.7 Human Machine Interface

2.4.7.7.1 General

The Human Machine Interfaces (HMIs) shall consist of an integrated SCADA/HMI PC-based graphic display system to support an interactive dialogue between the operator and the power plant equipment.
The HMI shall be based on an industrial touch screen, panel mounted computer, which shall be mounted on the Station Services PLC panel or, in the case of single unit stations, on the Unit Control Panel.

The HMI computer shall incorporate a solid state hard drive, and shall be designed for operation from a 110V DC power supply.

The HMI package shall include alarming, reporting, event logging and trending capabilities.
The HMI package shall include an interactive display editor.

All displays (formats and design) shall be subject to review by Project Manager.

The Contractor shall be responsible for integrating as a minimum the following displays:

a) Alarm Lists. Display of alarms. The entries in the alarm lists shall be arranged in chronological order.
b) System events summary. A chronological listing of all system events, i.e., alarms and operator-initiated actions.
c) Sequence of events list (one list).
d) Unit generation displays.
e) Station service displays.
f) Control system configuration display.
g) Generator and turbine capability curves with operating point shown.
h) Single line diagrams.
i) Headpond levels.
j) Penstock isolation valve display.
k) Sequence Monitor. The sequence monitor function shall monitor the sequential operation of the unit by checking the processing time for each step of the normal start and stop sequences. In the event of trouble in any sequential step, the step and equipment/devices shall be indicated on the sequence monitor to be mounted on the operator console.
l) Temperature Monitor. The winding temperatures of the generator, and generator step-up transformer winding temperatures shall be monitored with reference to the load and shall be continuously compared with the design characteristics. When an abnormal temperature trend is detected the related temperature-monitoring image shall be displayed. Display shall include a unit vertical section graphic indicating the location of the temperature sensors of the machine.

m) Daily and monthly reports.
n) Help screens.
o) Additional displays shall be as required by other functions included in this Contract.

2.4.7.7.2 Software Requirements

The operating system for the PC-based stations shall be Microsoft Windows 7 compatible.

The HMI software must have an international license and there shall be no requirement for hardware 'dongle' type security devices.

The database shall be designed to support the following input types:

a) Analogue Inputs - Read an analogue value either directly from a PLC or from a register within a protection relay device, and automatically convert the raw count to engineering units.
b) Analogue Alarms - Alarm capabilities for alarm suspension and remote acknowledge.
c) Calculations - Perform arithmetic calculations based on other database inputs.
d) Digital Inputs - Sense logical state of a switch or relay directly from the PLC input module or from a bit in memory of a protection relay.
e) Digital Alarm - Alarm capabilities for alarm suspension and remote acknowledge.
f) Digital Output - Set a logical on/off state in an output relay either directly in the PLC output module or in a bit within the memory of a protection relay.
g) Each database point shall include an instrument tag name, hardware device name, address, specific parameters, signal conditioning requirements and point description. The database shall be shared with the PLC database so as to ensure commonality of tag names throughout all devices.
h) The database shall be stored as a standard Windows file.
i) The database maintenance facilities shall be totally integrated with the graphic display system.
j) The database shall use a high-level data manipulation language such as Structured Query Language (SQL).

2.4.7.7.3 Security Management

The HMI software shall provide a user-based security system. If enabled, the security system shall allow for the creation of users with certain rights and/or privileges. These rights must include the ability to run any combination or all of the applications in the data acquisition system.

The ability to allow or disallow users' access to change values, such as setpoints and machine-setups, on an individual tag basis shall be supported.

2.4.7.7.4 Historical Data Management

Historical Data shall be collected at periodic intervals and stored in historical files, classified by type.
The periodicity of data collection and storage shall be different for each data type and shall be changeable for a specified period at the Operator's option.

The storage of collected real-time data in the historical files shall be in the same format as in the HMI database.

It shall be possible for the user to retrieve sets of data belonging to the same time sample or different time samples through a sort operation or through relational constructs and displays them in tabular form.

It shall be possible to archive historical files on optical disk for storage in a disk library.

2.4.7.8 System Performance and Testing

2.4.7.8.1 General Requirements

The Contractor shall meet the system functional and performance requirements given in these Employer's Requirements. The verification of compliance with the requirements shall be done through a series of tests focused primarily on functionality and system availability.

The testing sequence of the complete system shall consist of the following:

a) Pre-Factory Acceptance Test (Pre FAT).
b) Factory Acceptance Test (FAT).
c) Site Acceptance Test (SAT).

All system testing shall be made with the ultimate number of PLC and Operator stations and the ultimate number of points being simulated.

2.4.7.8.2 Acceptance Tests

The Contractors shall prepare a Factory Acceptance Test (FAT) Plan and shall submit it to the Project Manager for review and approval at least four (4) months before the scheduled start of system FAT.

The FAT Plan shall consist of the following:

1. FAT Overview
   This shall describe the test configuration, the hardware and software simulators used, the measurement tools, the complete test schedule, the forms for recording test results, the classification of discrepancies, and the processing of test reports.

2. Test Procedures
   This shall describe the test preconditions and assumptions, the detailed steps to be taken for each test and the verification of results of each step.
   a) The Test Procedures shall include both hardware and software tests.
   b) The Test Procedures shall have a separate section for the acceptance test procedures for the Plant Control System.
   c) A Pre-Factory Acceptance Test (Pre-FAT) shall be performed by the Contractor to verify that the system as fully integrated complies with all of the required functional details and that the system satisfies the response and resource utilization requirements.

d) The Pre-FAT shall follow completely the test procedures of the FAT Plan reviewed by the Project Manager.
e) The Project Manager may choose to witness the pre-FAT.
f) The Contractor must correct all discrepancies found in the pre-FAT before the Factory Acceptance Test can be started.
g) Project Manager or representative will witness the FAT upon notification by the Contractor that the system is ready for the FAT.
h) The FAT shall verify that the system as fully integrated complies with all of the required functional details and that the system satisfies the response and resource utilization requirements.
i) All discrepancies found in the FAT shall be corrected prior to shipment of the system.
j) After the system has been installed and checked out completely on site to the satisfaction of the Project Manager, Contractor shall perform the Site Acceptance Test (SAT). As part of the check-out, the SAT shall be preceded by a system generation of the clean software free of any remaining errors found in the FAT.
k) Essentially the SAT procedures shall be a repeat of the FAT test procedures under actual field conditions. Some of the FAT procedures shall be modified by the Contractor to reflect the field conditions.
l) At the end of the SAT the software shall be free of any 'forces' or other temporary bypasses.

2.4.7.8.3 Specified Spare Parts

The Contractor shall furnish spare parts for the control systems as listed below. A set is defined as the total number of each component required for one control system. One set of spare parts shall be provided. Where listed components differ between control systems supplied, one set shall be provided for each design of c.

- One PLC power supply
- One PLC processor.
- One of each type of IO module.
- Other items recommended by the Contractor.

2.4.8 Communication Systems

2.4.8.1 Type and Description

The Contractor is to design and install the following communication systems:

- Control system redundant fibre optic LAN at the powerhouse.
- A fibre optic communications cable linking the powerhouse controls to the penstock valve and dam level transmitter.
- SCADA system DNP3 communications linking intelligent electronic devices (IED's) at the powerhouse to the Employers SCADA at the NCC.
- Extension of the Employers VHF radio network for voice communications between the powerhouse and NCC.

The Employer will provide a single mode fibre optic cable to the power station building for the SCADA communications. The Contractor shall provide a fibre optic termination frame and terminate the single mode fibre cable. All fibre optic cable, transceivers, convertors etc required to interface the power station controls and protection scheme to the Employer provided cable shall be provided by the Contractor.

2.4.8.2 Fibre Optic Network Features

2.4.8.2.1 Fibre Patch Panels

Fibre patch panels shall be provided at:-

- The Powerhouse
- Headpond

Each individual fibre core of all cables shall be terminated into SC type receptacles in the patch panels.
All fibres are to be terminated with type 'SC' connectors. Preformed fiber patch cables shall be provided. These shall be colour coded in accordance with the service they are associated with. The coding shall be:-

- Blue for control system LAN.
- Green for SCADA DNP3 network.
- Red for protection signalling.

No patch cords in excess of 15m long are permitted.
All fibres are to be fully tested 'point-to-point' i.e. from the source device to the destination device with all interconnecting 'patch' cables installed. The attenuation over the entire length of each fibre is to be measured and recorded and each length measured using an OTDR to check for any significant step changes in attenuation. Any loss greater than that expected and commonly recognised as being 'typical' is to be thoroughly investigated and the suspect/faulty component replaced and the complete length retested. A record of the measured loss and OTDR profile for each fibre is to be submitted for the Project Managers approval and once approved, included with the 'as-built' documentation.

2.4.8.2.2 Power Station Control System LAN

Power station control LAN's shall be 'fault-tolerant', redundant, fibre optic based 100 MBPs 'Ethernet' network. All network links between steel enclosures shall be fibre optic. Network connections within steel enclosures or between adjacent steel enclosures shall be implemented using either fibre or CAT 6 cabling.

The LAN shall link the following devices on the Plant control system:

- The Station PLC, located in the Station control panel.
- The Unit PLCs, located in the Unit control panels.
- Remote IO, located at the headpond for the penstock valve and headpond level transmitter.
- HMI workstations, located in the power station control room.
- One monochromatic printer, located at the power station control room.

Failure of any single device shall not affect the integrity of the overall LAN.

Network switches, hubs and routers shall be provided as necessary. These devices shall be located in the same enclosure as the PLC / HMI operator interface or in a wall or desk mounted enclosure for the HMI workstations. No switch, hub or router shall be connected to both main and backup sections of the redundant plant control system LAN. All switches, hubs or routers shall be provided with redundant power supplies taken off the powerhouse 110V DC system.

The station control system LAN cabling shall be run in stainless steel conduit over all sections external to steel panels.

2.4.8.2.3 SCADA Network

The Contractor is to design and implement a transport network for a Level 2 DNP3 communication between IED's and a SCADA master located at the Employers NCC.
The Employers NCC uses ClearSCADA manufactured by Schneider Electric Ltd.
As a minimum the DNP3 network shall link the following IED's to the SCADA RTU:

- The generator protection relays.
- The transformer protection relays.
- The 22 kV Feeder protection relays.
- The Station PLC

Failure of any single device shall not affect the integrity of the overall DNP3 network.
Network switches, hubs and routers shall be provided as necessary. These devices shall be located in the same enclosure as the IED. All switches, hubs or routers shall be provided with 110V DC power supplies.

2.4.9 Protective Relaying System

2.4.9.1 Type and Description

The protective relaying system shall be utilized for the protection of major equipment including generators, step-up transformers, and 22 kV Feeder.

Relaying shall consist of multifunction, multiprocessor-based digital relays having the protective functions as indicated.

2.4.9.2 General Requirements

Protective relays shall be solid state, multi-function, flush mounted with dust tight covers. Isolating and shorting facilities shall be provided for prevention of opening of current circuit on withdrawal of the relay.

Protective functions shall be configured to be fail safe and the protected Plant shall be tripped in the event of a fault within the protection system, including partial loss of DC supplies.

Protective relays shall be supplied with all necessary auxiliaries such as auxiliary instrument transformers, filters, rectifiers, etc. as required. They shall be provided with testing facilities and operation indicators (flags) with manual reset push buttons.

All protective relays, unless otherwise specified, shall be for operation from instrument transformers having nominal 1 amperes and $110/\sqrt{3}$ volts secondary's and from 110-V DC station battery. The Employer requires that protection relays associated with the 22kV Feeder shall be as manufactured by Schweitzer Engineering Laboratories (SEL). The Employer prefers that all other protection relays utilised on the project are also of SEL manufacture.

All protection required for the generating units and generator transformers shall be mounted on the Unit Control Panels. Devices shall include all protective relays, automatic and manual synchronizing devices, and any machine condition monitoring equipment.

Secondary circuits of the instrument transformers shall be connected to the test block permitting separation from the low voltage equipment fed by them. Shorting terminals shall be provided for all current transformer cores. All voltage relays shall have sufficient thermal capacity for continuous energisation, using external resistors if necessary.

All relays and instruments shall be provided with an identification nameplate. The nameplates shall be of engraved laminated black on white Bakelite or equal material.

Tripping relays (device 86) shall be high speed, manual reset, and multicontacts type. One tripping relay shall provide for each protective relaying system. Tripping relays shall be front-of-panel mounted, complete with targets and a white indicating light used to supervise the status of the tripping coil. The relays shall have manual reset provisions from a pushbutton on the relay as well as electrically via the HMI.

2.4.9.3 Turbine Generator & Generator Transformer Protective Relaying System

2.4.9.3.1 General

The protective relaying system shall be designed to protect the synchronous generator, step up transformer and the turbine. The trips shall be arranged in three operational groupings to allow for different protective actions to be taken depending on the nature of the fault.

Designation	Function	Description
Trip A (86A)	Turbine Generator Trip Loaded	Trip unit CB and turbine immediately when a serious fault is detected.
Trip B (86B)	Turbine Generator Trip Unloaded	Unload unit, then trip turbine and unit CB.
Trip C (86C)	Generator Trip	Disconnect the unit when an external system electrical fault is detected. Unit may synchronise back onto the grid when the appropriate Operator command is given via SCADA.

Each turbine generator shall be provided with an 'all in one' generator protection relay supplemented by trips initiated by the Unit PLC and hardwired devices. In general the generator protection relays shall be used for faults of an 'electrical' nature (eg differential protection), with the Unit PLC being used for faults of a 'mechanical' nature (eg bearing temperature). Critical safety trips (eg turbine overspeed) shall be hardwired.

The **minimum** trip initiating functions required are listed in the sections that follow. The Contractor shall add to this list any additional functions that are required to adequately protect the Plant provided against all foreseeable fault events.

2.4.9.3.2 Turbine Loaded Trip A

Trip A initiates an immediate "emergency" shutdown of the turbine generator without unloading. The following table details the minimum protection functions required.

Function Description	ANSI Code
Over-excitation Protection (V/Hz)	24
Synch Check. (CB close block only)	25
Under Voltage	27
Under Excitation Protection	40
Thermal Overload	49
Definite Time over-current	50/51
Overvoltage	59
Generator/Transformer Overall Differential protection	87U
Forward Power	32F
Reverse Power	32R
Inadvertent energisation	50/27
Sensitive Earth fault protection	50/51GN
Inverse Time over-current protection	51V
Stator Earth Fault	59N

The following devices shall also be hardwired into Trip A:-

Function Description	ANSI Code	From Device
Emergency Stop Trip push button	5	Pushbutton on unit control panel
Unit Over speed device	12A	Over speed device
Governor Accumulator Low Pressure Trip	65P	Pressure switch on accumulator
AC or DC lubrication pump fail		Pump starter
Lubrication oil low flow		Flow switch on bearing oil lines
Generator Transformer Buchholz	63BT	Transformer Buchholz or Pressure Relied Devices
Station PLC Order trip	SPLC	Emergency trip from Station PLC
Unit PLC Watchdog	UPLC	NC contact from Unit PLC

In the event of one of these faults, the initiating device shall energise the Trip A Relay, which shall operate:

- 22 kV Breaker Trip Circuit.
- Governor Emergency Shutdown Device.
- Inlet Valve Emergency Shutdown circuit.
- Excitation Trip

After the unit has shutdown, it shall be locked out from restarting until the protection relay, and the trip relay have been reset. This is done either locally on the unit protection panel, or remotely from the Plant Control System.

2.4.9.3.3 Turbine Trip Unloaded - Trip B

Trip B initiates a turbine unload sequence before tripping the turbine and 22 kV circuit breaker. In general it will be used for trips required for a mechanical fault with the generator or turbine. The trip is handled by the Unit PLC, using readings from instruments monitoring the unit.

Function Description	ANSI Code
Control AC/DC power supplies fail	33
Penstock Pressure low trip	63
Bearing Temperature high trip	38T1
Bearing Sump oil over-temperature	38T3
Bearing Vibration high	38V1
Stator Winding temperature	49T1
Cooling water temperature high	49T4
Governor accumulator low level trip	65L
Governor low pressure trip	65P2
Tailwater high level trip	71
Generator Transformer Winding Temperature	49T5
Generator Transformer Oil Temperature	49T6
Generator Transformer Oil Level	71LT

On the occurrence of this trip the PLC shall lockout the unit and prevent it from starting until reset locally on the protection reset button, or from the station HMI.

2.4.9.3.4 Trip C

Trip C is an external system electrical fault. The objective of this trip is to disconnect the unit from the grid to prevent damage to the generator. The unit shall go to speed no load mode with excitation left on. In this mode, the unit shall be ready to re-synchronise with the grid quickly.
The trip will be ordered by the unit 'all in one' protection relay.

Function Description	**ANSI Code**
Under frequency	81L
Over frequency	81H
Negative sequence over-current	46

2.4.9.4 22kV Feeder Protection

2.4.9.4.1 General

The Feeder protection shall be designed to protect the 22 kV Feeder and ensure the clearance of faults in the shortest time possible so as to minimise the disruption to the Employers transmission system.
The Contractor shall implement the 22kV Feeder protection using a SEL351A feeder protection relay.

The scheme shall include synch check. Auto-reclose functions shall be blocked.

2.4.9.4.2 Protective Features

The following table details the protection functions required and the allocation between the two protection relays

Function Description	**ANSI Code**
Impedance (Distance) Protection	21
Synch Check	25
Thermal Overload	49
Instantaneous Overcurrent	50
Beaker Failure	50BF
Inverse Time Overcurrent	51
Directional Phase Overcurrent	67
Directional Overcurrent (Earth Fault)	67N

2.4.9.5 General Protective Relaying Requirements

2.4.9.5.1 Trip Circuit Supervision

Each trip circuit shall be provided with a trip circuit supervision relay monitoring both the status of the trip circuit DC supplies and the integrity of the trip circuit wiring.

2.4.9.5.2 Time Synchronization

The protection relays at the powerhouse shall be time synchronized to an IRIG-B signal. Event reports generated in the different protection relays are to be time stamped to within 10 µs of each other.

2.4.9.6 SCADA Interface

The Protection Relays are to be interfaced with the Employers SCADA system using DNP3.

2.4.9.7 Specified Spare Parts

The Contractor shall furnish spare parts for the protection systems as listed below. A set is defined as the total number of each component required for one protection system. One set of spare parts shall be provided. Where listed components differ between protection systems supplied, one set shall be provided for each design of protection system.

- One generator protection relay.
- Two trip relays.
- Other items recommended by the Contractor.

2.4.10 DC Systems

2.4.10.1 General

The Contractor shall furnish all labour, materials, and equipment required to design, supply, install, field test, and pre-commission battery backed up DC system for the powerhouse control, protection and SCADA, communications.

The system shall normally supply 110 V DC to the powerhouse systems by utilizing the DC output from the battery chargers to feed the 110 V DC switchboard. When the 415/240 V AC power supply to the battery chargers fails, the battery sets shall provide 110 V DC to the 110 V DC switchboards.

110 VDC power supplies shall consist of:

- Two Battery banks each rated for 50% of station 110VDC load (including new 3rd generator).
- Two Battery chargers each for 100% of station DC load plus the capacity to recharge one battery bank in 8 hours
- One DC distribution board including paralleling diodes.
- DC distribution.
- 110V DC shall be used for all protection and control functions.

The Contractor shall provide all necessary associated equipment, special tools, controls and detailed information for the installation, testing, pre-commissioning and operation of the equipment supplied.

2.4.10.2 Battery Sets

The batteries shall be valve regulated lead acid (VRLA) type complying with IEC 60896-21 and 60896-22.

The batteries shall be designed for a minimum service life of twelve years to 80% remaining capacity. The battery rating shall be increased to allow for an 80% end-of-life capacity (i.e. battery increased by 1.25).

Each battery set shall have the capability of being completely discharged to the 1.8 V per cell rating over a 4-hr period a minimum of 50 times over the 12-year life period.

The plates shall be assembled in plastic jars of heat-resisting and shock-absorbing material which will not warp, bulge, or lose its shape. The jars shall provide a permanent seal at the joint of the jar and cover and shall be easily cleaned. Plastic cell jars shall be clear with no colouring.

Cell covers shall have flame arrester type vent caps.

The cables from the batteries to the DC charger/distribution panels shall be electrically protected by fuses located as close as practical to the battery terminals. DC positive and negative cables shall not run in close proximity until after the fuse protection.

2.4.10.3 Battery Rack

The battery cells shall be located on a battery rack at a convenient height and shall be easily replaceable. The rack shall be of the stepped type with a maximum of 2 steps and made of galvanized steel. It shall permit easy maintenance and cleaning of the battery set and the battery room floor. It shall allow a compact assembly of the cells to assure maximum voltage across the battery. The rack shall be painted with 2 coats of acid resisting paint.

Note: the battery voltage test point on the battery terminals shall not be higher than 1800mm above floor level.

2.4.10.4 Battery Chargers

Battery chargers shall:

- be housed in a heavy gauge sheet metal cabinet. The cabinet shall be free standing, floor or wall mounted. Access shall be from the front through a hinged door
- be regulated, thyristor controlled with fully automatic controls.
- Be designed for use with VRLA batteries.
- be self-ventilated for operation in an ambient temperature not to exceed 40°C or below 0°C
- be capable of float charging the battery set and simultaneously supplying other loads to its full ampere capacity.
- be provided with an adjustable current limiting feature that will limit the output current to the maximum recharge current recommended by the VRLA battery manufacturer.
- Be provided with temperature compensation to prevent over charging or thermal runaway of the batteries. A remote temperature sensor shall be provided for <u>each</u> battery cell.

- have a voltage regulation of ±1.0% from no load to full load with a ±10% supply voltage variation
- operate properly over a ±5% supply voltage frequency variation.
- be capable of picking up a fully discharged battery without tripping.
- be designed for parallel operation with a second battery charger.
- have a two or more winding transformer to isolate the AC supply from the DC output
- have reverse-current protection to prevent draining the battery in the event of rectifier failure or short circuit

The A-weighted sound level shall not exceed 60 dB when measured at a distance of one meter from the charger enclosure. The sound level shall be measured while the charger is operating at rated voltage and frequency and at maximum rated output current.

The chargers shall have surge suppressors and filters to prevent voltage spikes or other distortion from being fed back into the AC power supply or from affecting the DC output. The filters shall limit the voltage transients to not more than 5% of the fundamental. Output ripple content shall be limited to less than 2% rms.

Thermal magnetic circuit breakers of suitable current carrying and interrupting capacity shall be used in the following applications:

a) Alternating Current Input
   All chargers shall have a thermal magnetic circuit breaker.
b) Direct Current Output
   All chargers shall have a 2-pole thermal magnetic circuit breaker. Breakers shall have a minimum interrupting rating of 20,000A.

Each battery charger shall also be equipped with the following:

a) Output DC voltmeter.
b) Output DC ammeter.
c) AC power failure relay, with one normally open and one normally closed contact and a local pilot light.
d) DC low and high voltage alarm relays, each furnished with one normally open and one normally closed contact. A local pilot light shall be furnished for each relay.
e) DC ground detection relay for remote alarm with local pilot light.
f) AC power "ON" pilot light.

Each battery charger nameplate shall contain:

a) Manufacturer's name.
b) Model, type, and serial number.
c) AC voltage and frequency.
d) Number of phases.
e) AC ampere rating.
f) DC voltage rating.
g) DC ampere rating.

2.4.10.5 DC Main Distribution Boards

DC distribution boards shall be designed and constructed in accordance with AS/NZS 3439.1 and AS 2672.2, as applicable. Where compliance is not relevant the board shall be designed for the fault rating expected using industry standard components.

All circuit breakers shall be at least two-pole, breaking both the negative and the positive lines. All MCCBs shall be fitted with panel-front mounted rotary handles.

2.4.11 General Electrical Requirements

2.4.11.1 General

Unless otherwise specified, auxiliary electrical equipment shall conform to all applicable standards of the authorities as specified in Section 6 Part 0 Standards. Note that in the Samoa the requirements of the Australian wiring regulations AS/NZ3000:2007 and referenced standards are the paramount requirements.

The Samoa electricity system uses a Multiple Earthed Neutral (MEN) system which is described as a TN-C-S under IEC60364.

2.4.11.2 Phase Rotation

Generator and motor phase rotation will be designated as R for the 1st phase (U-X), S the 2nd phase (V-Y), and T for the 3rd phase (W-Z). Power phase rotation will be designed as R-S-T. R-S-T type bus arrangements, left-to-right, top-to-bottom and front-to-rear, will be used throughout to assure convenient and safe testing and maintenance.

2.4.11.3 Control Equipment Electrical Ratings

2.4.11.3.1 Voltage Ratings

Control equipment shall be designed for operation at the following voltages:

- Nominal rating 110-V DC with an operating range of 88 to 132V DC, ungrounded from the station battery.
- Nominal rating single-phase 240-V AC, 50-Hz, grounded, with an operating range of ±10%.

2.4.11.3.2 Electrical Contact Ratings

- Contacts shall be suitable for the application and have current and voltage ratings that will not be exceeded when applied in the control circuits.
- Contacts intended for use in the control circuits shall be electrically-independent, ungrounded, dry contacts, field changeable from "normally-open" to "normally-closed" and have the following ratings:
- Maximum Design Voltage. 415/240-V AC and 110-V DC.
- Continuous Current. 5-A AC or DC.
- Maximum Interrupting Current. Inductive (when L/R≥5000), 1.5-A at 240-V AC and 1.1-A at 110-V DC.
- Maximum Making Current. Inductive (when L/R≥5000), 15-A at 240-V AC and 1.1-A at 110-V DC.

2.4.11.4 Motors

2.4.11.4.1 Standards

Motors shall comply with IEC 60034 as regards performance and testing.

Ratings and Characteristics

- Frequency (AC motors): 50-Hz.
- Voltage (AC motors): 0.75-kW and above, 3-phase, 415-V; less than 0.75 kW, 1-phase, 240-V
- Insulation: Class B, nonhygroscopic.
- Enclosure: totally-enclosed, fan-cooled, (TEFC) unless otherwise specified.
- Accessories. The following accessories shall be provided:
- Non-ferrous, metal guard screens on all ventilating openings.
- Lifting eyes (eye bolts) on all motors weighing more than 50 kg.
- Space heaters for motors above 50 kW shall be factory mounted in an accessible location under the stator frames and rated to maintain internal temperature approximately 10°C above ambient temperature specified. Heater leads shall be wired to a separate terminal box mounted on the motor. Heaters shall be low watt-density and connected to the motor starter control circuit. Heaters shall be automatically energized when the motor is shut down.
- Ground pads with tapped bolt holes on 2-hole standard centres for motors rated 15 kW and above. Pad locations shall be near the base and shall be shown on manufacturer's motor or assembly outline Drawings.
- Soleplates and hold down bolts, where required.
- Gasketed motor terminal boxes, sized to accommodate external cable and lugs, and suitable for conduit connections. They shall be suitable for rotating in 90º steps.

2.4.11.4.2 Service Factor

All motors shall be sized to permit the driven equipment to develop its specified capacity continuously without exceeding the rated temperature and using no more than 85% of rated motor kW capacity (1.15 Service Factor). The intent of this requirement is that the motor kW capacity be sized above the maximum continuous duty required by the driven equipment.

2.4.11.4.3 Bearings

Bearings shall be liberal in size, suitable for continuous service under the conditions specified, sealed against the entrance of dirt and the escapement of the lubricant.

Fitted openings shall be provided on the bearing housing for applying and draining the lubricant. Filler and drain extensions shall be furnished where necessary to give ready accessibility.

Wherever necessary, the bearings shall be insulated to prevent the passage of shaft currents through the bearings.

The thrust bearing for vertical motors shall be of the antifriction type, capable of supporting the weight of the motor and driven equipment rotating parts plus hydraulic thrust due to load. Bearings shall be grease lubricated with provisions for greasing. Provisions shall be made to prevent over-greasing where excess lubrication may cause damage.

2.4.11.4.4 Starting

- Except where specifically indicated otherwise, motors shall be suitable for full-voltage, across-the-line starting.
- Motors shall accelerate the driven equipment to rated speed with 80% of the motor nameplate voltage applied at the terminals. Unless otherwise approved, the maximum starting current shall not exceed 6 times the rated full-load current.
- Motors shall withstand without adverse effects, a full voltage, dead-bus transfer from one source to another. The minimum "dead time" for this transfer shall be considered to be 1 second.
- Where repetitive starting is necessary, the permissible number of starts shall be clearly indicated on the nameplate.

2.4.11.4.5 Finish

Motors for use indoors shall have the manufacturer's standard finish unless otherwise specified. Motors for outdoor use shall have corrosion-resisting hardware and corrosion-resisting finish on the rotor and shaft.

2.4.11.5 Cabling Installation Practice

2.4.11.5.1 General

All cables shall be run parallel to walls and either truly vertical or horizontal as appropriate. Agree all exposed cable routes with the Project Manager prior to commencing work. All holes through structural members shall be approved by the Project Manager before drilling commences.

Ensure that all cables are supported to avoid undue strain on cables or on terminations. All cabling shall be neatly dressed, run in single layers and identified as to function at terminating points. All cabling shall be installed in a manner which permits its convenient withdrawal and replacement. No cable shall be cast directly into concrete.

Sharp edges to steel or sheet metal shall be removed and such work shall be arranged to avoid accidental injury to personnel, or damage to insulation. Provide insulated bushes at all points where cables enter metal enclosures.

2.4.11.5.2 Cable Identification

Each cable shall be labelled with a permanent identification number as indicated on the Contractors cable schedules. All cable cores shall be numbered.

2.4.11.5.3 Underground Cables

All underground cables are to be buried in a trench at a minimum depth of 600mm, bedded on not less than 100mm of fine washed sand and covered by a further 100mm of sand. The cables are to be laid free of kinks and twists and laid in flat formation without interlacing.

The trench shall be backfilled with 150mm of soil, consolidated and a protective layer of 150 x 25 RS ground retention tanalith treated timber, or approved proprietary cable protection covering is to be placed over the full length of the trench.

Cabling is to be completed covered by timber or equal protection.

Lay on Orange PVC signal strip 100mm wide with "Electric cable below" or equal labelling, above cables over fully length of route, at a depth of 250mm. Locations of underground cables are to be accurately marked on the Contract drawings. Where underground cables enter building a warning sign indicating "danger buried cable" is to be fastened to the building 200mm above ground level.

2.4.11.5.4 Cable Ladder

Provide all necessary cable ladder to support cables. All cable ladder width shall be sufficient for the work plus 30% spare capacity.

Cable ladder shall be manufactured from aluminium and shall be of NEMA 12A type.

Cable ladder shall be stood off the wall on galvanised spacers or brackets or suspended from the ceiling using a proprietary cable ladder hanger system. Maximum spacing of supports, brackets and hangers shall be 2 meter. Cable ladder shall be capable of supporting 12.5 kg/m per 100mm, i.e. a 600mm wide cable ladder must be capable of supporting 75 kg/m.

All runs of ladders shall be continuously bonded and earthed.

For all HV cabling, proprietary cable clamps must be used.

Ladders shall not be mounted directly onto flat surfaces. Install on suitable brackets clear of the surface to allow for cleaning and sufficient space for air circulation around and through the ladders.

2.4.11.5.5 Cable Installation Practice (HV Cables)

Single core cables shall be laid in trefoil formation using approved trefoil clamps at intervals of no more than 1m. All cables shall be pulled, supported and terminated in accordance with manufacturer's instructions.

All copper wire screens and steel wire armour shall be bonded and earthed at both ends.

Joints in cable runs shall not be permitted.

All exposed cables shall be run parallel to walls and either truly vertical or horizontal as appropriate.

Cables to transformers may be supported as necessary using galvanised saddles fixed to the equipment frame but on no account shall penetrations be made in tanks containing oil.

At termination boxes cables shall be glanded. All terminations shall use compression terminals.

The Contractor shall ensure that:

a. All cables shall be glanded using stainless steel glands incorporating a waterproofing seal. All terminations shall use pressure crimp lugs, compressed using the correct tool.

b. Glanding and termination of cable is carried out strictly in accordance with manufacturer's instructions.

c. All bolts used in termination shall be stainless steel fitted with plain washer and two nuts. The torque of all bolted connections for cables over 70mm2 shall be recorded.

d. PVC shrouds are fitted to outdoor cables and/or that any future creepage will not leave armouring exposed.

e. Two locknuts are fitted to each gland and that each gland is fitted to a gland plate or bracket.

f. Bushes are fitted on each gland.

g. Cable glands and cable sheaths are effectively connected to the earthing system. Earth connections must have a cross section not less than 50% of the cross section of a core of the associated cable.

h. Under no circumstances shall copper and aluminium conductors be directly connected.

2.4.11.5.6 Cabling Installation Practice (LV Cables)

All exposed cables shall be run parallel to walls and either truly vertical or horizontal as appropriate. Cables shall be run on either cable ladder or floor ducts as appropriate.

Cables shall be sized to achieve a voltage drop of less than 2.5% of the nominal voltage between the distribution board and fitting. The maximum voltage drop from the station services transformers to the final sub circuit shall be no more than 5%.

Ensure that all cables are supported to avoid undue strain on cables or on terminations. All cabling shall be neatly dressed, run in single layers and identified as to function at terminating points. All cabling shall be installed in a manner which permits its convenient withdrawal and replacement. No cable shall be cast directly into concrete. In such areas install cables in conduit or ducting. Draw wires shall be installed in conduits or pipes where necessary for later cable installation.

Sharp edges to steel or sheet metal shall be removed and such work shall be arranged to avoid accidental injury to personnel, or damage to insulation. Provide insulated bushes at all points where cables enter metal enclosures.

After installation but before connection, all power cables shall be tested for insulation resistance. Cabling shall be cleated at centres not exceeding:-

: 450 mm horizontally

: 900 mm vertically

On no account shall plastic sheathed cables be run in any situation where timbers have been treated or likely to be treated with tar-oil, creosote or allied products.

No ordinary grade PVC insulated cables shall be run in any location where the temperature is likely to exceed 45°C. No high temperature grade PVC shall be run in locations where the temperature is likely to exceed 75°C. Mineral insulated cable shall be used where the temperature may exceed 75°C.

Wiring which supplies equipment liable to overheat and cause rapid deterioration of the wiring, shall have the tails made off with heat resisting sleeves to protect the permanent wiring in a conduit box. The conduit box shall be fitted with terminals and mounted adjacent to the fitting or equipment with a run of heat resistant cabling from the box.

2.4.11.5.7 Cable Installation Practice (Instrumentation Cables)

The following installation practice shall be used:

- Cable shields shall be electrically continuous. When two lengths of shielded cable are connected together at a terminal block, an insulated point on the terminal block shall be used for connecting the shields.
- Shields shall be isolated and insulated except at their selected grounding point to prevent stray and multiple grounds to the shield.
- At the point of termination, the shield shall not be stripped back any further than necessary from the terminal block.
- For signal circuits, the shield must not be part of the signal circuit.
- Signal circuits shall be grounded at only one point.
- Digital signal circuits shall be grounded only at the power supply.
- Analogue signal circuits shall be grounded only at the control panel and on a clean earth.
- Analogue signal cables shall be physically segregated from all power and control cables and from unshielded cables carrying digital or pulse type signals.
- All signal circuits to outdoor equipment shall be fitted with transient filters for protection against lightning.

2.4.11.6 Cabling

2.4.11.6.1 240/415V Cables

Cables shall be a minimum of 600/1,000 volt rating for 415 volt line voltage use.
All low voltage power cables are to have copper conductors and are to be run in accordance with NZS 3000 : 2007. Cables shall comply with the following standards:-

PVC insulated : NZS 6401
: AS/NZS 4961
: AS/NZS 5000.1

XLPE insulated : AS/NZS 5000.1
: AS/NZS 4026
: AS/NZS 4961

Neutral Screened : AS/NZS 3155

All cables shall be installed in accordance with AS/NZS 3000 and shall be rated in accordance with AS/NZS 3008.1.2.

All power cables shall have stranded copper conductors.

2.4.11.6.2 Instrumentation Cabling

Type.	Twisted pairs or triads (RTD's) with an overall shield.
Conductor	Stranded, tinned copper, 0.5 mm2 or larger.
Insulation Type	PVC
Rated Voltage (not less than)	150-V DC
Continuous operating temperature	105°C (dry)

The insulated conductors shall have an overall aluminium foil shield bonded to a mylar or polyester film with a stranded, tinned copper, continuous drain wire outside of the shield.
Each pair/triple shall be marked with indelible numbering.
Analogue signals shall be run in separate cables from digital signals.

2.4.11.6.3 Control Cabling

Type	Unarmoured, circular, multicore with an integral earth conductor.
Conductor	Stranded, copper, 1.5 mm2 or larger.
Insulation Type	PVC
Rated Voltage (not less than)	1000-V AC
Continuous operating temperature	90°C

Each core shall be marked with indelible numbering.

All cores in one cable shall operate at the same voltage.

2.4.11.6.4 Earthing and Equipotential Bonding

Effective protective earthing and equipotential bonding shall be provided, in accordance with AS/NZS 3000, for all electrical equipment installed under this contract. The Contractor must ensure all metal work encasing electrical work is bonded to earth. This shall include bonding all trays, ladders, trunking and electrical equipment.

2.4.11.7 Panel and Switchboard Construction

2.4.11.7.1 General

Panels and switchboards shall comply with AS/NZS 3439.1:2002: Low-voltage switchgear and controlgear assemblies - Type-tested and partially type-tested assemblies.

2.4.11.7.2 Metalwork

All enclosures used to house electrical equipment shall be gasketed, vermin proof and protected to the class specified in accordance with IEC 60947-1. If not stated, the minimum class shall be IP42. The maximum height above floor level of all instruments, control switches and relays shall allow for easy operation of the Plant and shall not exceed 1.80 m.

Enclosures shall consist of rigid, self-supporting, steel panels with a minimum thickness of 1.5 mm steel that have full-length, hinged and gasketed doors, located to provide easy access to the equipment. A tamper-proof lock shall be provided on each door of the enclosure. Interior panels shall be provided inside the enclosures for mounting items of electrical equipment.

All panels shall be located on a 75mm high plinth made of steel or concrete, as applicable to the general construction.

Mild steel panels are not permitted. All panels shall with use grade 316 stainless steel or galvanized steel construction. Steel shall be passivated, powder coated finished with baked enamel paint. Any outdoor panels, or panels in a damp area shall be grade 316 stainless steel.

Full height doors shall be provided with door stays to prevent swinging when open. All panel doors shall be hinged and shall be provided with T'bar locks. At least one T'bar on each compartment shall be key lockable. The same key pattern shall be used for every lock on the whole assembly and a set of keys (minimum of 10) shall be provided with the assembly.

All fastenings shall be integral with the panel or door and provision made for locking. Doors shall be rigid and fitted with weatherproof sealing material suitable for the climatic conditions specified. No door shall be wider than 1200mm without the permission of the Project Manager. Panel positions in general and door sizes and positions when open, shall not impinge on the safety and operability requirements of these clauses.
Outdoor panels shall be well ventilated through vermin-proof louvres comprising a filter screen attached to a frame and secured to the inside of the panel. Divisions between compartments within the panel shall be perforated to assist air circulation. If required, ventilation fans shall be used.

2.4.11.7.3Terminals

All terminals shall be mounted in accessible positions. Adjacent terminals shall be adequately spaced to each other and to the incoming cable gland plate. Separate terminations shall be provided on each terminal strip for the cores of incoming and outgoing cables including all spare cores.

All terminals having a circuit voltage of 240V or higher shall be separated from lower voltages by a space created with partitions or end plates combined with end brackets and shall be shielded with an insulated cover marked with a warning notice "Danger ..... Volts". Where necessary, the different 240V / 415V phases shall be shielded from each other with partitions (i.e. where the in-service or under-maintenance breaking of a phase-wire can result in a phase to phase short circuit due to the type of terminal used).
Terminal blocks shall not be located less than 200mm from cable gland plates.

Only one conductor shall be terminated in each side of the terminal block.

Shorting straps shall be used between terminal blocks to bridge identical conductor terminals. Cubicles shall have at least 10% spare terminals and enough extra space on mounting bars for another 20% terminals.

2.4.11.7.4 Neutral & Earth Bars

These shall be a generous size to enable convenient termination of all neutral and earth conductors. Neutral and earth bars shall be provided with purpose made terminations sufficient for all connections with 25% spare. The bars shall be brass, tunnel type with slotted grub screw termination fixing and shall be rated at not less than the full current carrying capacity of the main supply. Terminations are to be provided for incoming neutral and earth cables of sizes shown on the drawings or as required by AS/NZS 3000.

Busbars and connected circuits shall be capable of carrying continuously a total load equal to the rated capacity of the incoming switch isolator without the temperature rise of any component mounted with or on a board exceeding 20°C.

The earth and neutral bar shall be located well clear of incoming cables and other connections.

Busbars& Connections

Busbars and connections thereto shall be fully insulated and shall comply with AS/NZS 3439.2. Busbars shall be capable of carrying the continuous rated current with a maximum temperature rise of 30°C above an ambient temperature of 40°C.

Clearances are to be maintained when a current equal to the specified short circuit rating is flowing in the busbars and connections and shall be capable of withstanding the specified test voltages. Busbars shall be rated at not less than the maximum current rating as indicated on the drawings and braced to withstand fault levels, which can be safely cleared by the section isolators.

2.4.11.7.5 Moulded Case Circuit Breakers (MCCBs)

Moulded case circuit breakers shall comply with IEC 60947-2.

The service breaking capacity (Ics) shall be 100% of the ultimate breaking capacity (Icu). The rated ultimate breaking capacity (Icu) of each moulded-case circuit breaker shall be equal to at least the value of the short-circuit current (Isc) at the point of installation on the electric circuit, unless the upstream circuit breaker makes it possible to ensure coordination as defined in Appendix A of IEC 60947-2.

MCCBs shall be of circuit breaker disconnector type and shall have a rated operational voltage of 690V AC (50/60Hz).

The rated insulation voltage of the circuit breakers shall be 750V AC (50/60Hz).
The MCCBs shall provide class II insulation (to IEC 664) between the front and internal power circuits.

The operating mechanism shall be of the quick make quick break type, with the speed of operation independent of the operator, and shall be trip free.

The breakers shall be operated by a toggle or a handle as specified which shall clearly indicate the three fundamental positions ON, and OFF and TRIPPED. If required, rotary handles shall be fitted to the breaker.

The operating mechanism shall be designed in such a way that the position of the operating handle of the circuit breaker indicates the real position of the main contacts (i.e. positive contact indication), even if the circuit breaker is equipped with a rotary handle.

Isolation shall be provided by a double break on the main circuit.

It shall be possible to lock the circuit breaker in the isolated position only with the use of a locking device and padlocks.

MCCBs shall have clearly accessible from the front face:
- Markings of rating
- Marked as suitable for isolation
- Push-to-trip test button to test operation of poles
- Contact position indicator

The MCCB shall provide double insulation of the front face to allow on-site installation of auxiliaries without de-energising the installation or circuit. All electrical auxiliaries and accessories including voltage releases (shunt or under-voltage) and auxiliary contacts shall be designed for easy on-site installation. All electrical auxiliaries shall be equipped with terminal blocks and shall be of the snap-in type. All electrical auxiliaries shall be separated from power circuits and their addition shall not increase the MCCB volume.

2.4.11.7.6 Fuses

Fuses shall be high rupturing capacity and type gG as defined in IEC 60269-1, IEC 60269-2-1 and have minimum breaking capacities equal to 80kA or greater. Fuses to be used for motor protection may be type aM.

In any case fuses shall have a minimum interrupting volt-ampere capacity at least equal to the fault rating at the switchboard specified herein.
Fuse ratings and the phase to which they are connected are to be legibly marked on holder and base. Provide (6) spare fuse links of each size and type used on the switchboard and locate in a purpose made compartment. Provide all spare fuse bases as indicated.

2.4.11.7.7 Miniature Circuit Breakers (MCBs)

Miniature circuit breakers (MCBs) shall comply fully with AS/NZS 60898.1. They shall be removable from the in-service position without removing adjacent circuit breakers and shall be of the trip-free type. The range available shall include breakers with B, C, D and MA tripping curves and shall be available in 6kA, 10kA and 15kA fault ratings. The breaker combinations of MCCB followed by MCB and further downstream MCBs shall provide full discrimination right through the circuit breaker installation.

MCBs shall have a fault rating of not less than the fault level of the distribution system at the point of connection in the switchboard but not less than 10KA. The use of cascading is permitted to provide an increase in a breaker's fault rating.

MCBs shall be capable of being padlocked open using suitable attachments.
A minimum of 25% spare ways shall be provided to allow for the future MCBs.

2.4.11.7.8 Discrimination Function

Discrimination shall be provided to comply with IEC 60947-2 and shall be total discrimination. This means that for faults from overloads up to the full prospective short circuit level of the system, only the circuit breaker immediately upstream of the fault shall operate to clear the fault and all other circuit breakers shall remain closed.

The Contractor shall provide computer-generated calculations in the form of an easily read report that proves discrimination. In the short circuit region, the results shall be based on tests that the protective device manufacturer has carried out that have been incorporated into computer model.

2.4.11.7.9 Motor Starters

Low voltage motor starters shall be of the combination type as defined in IEC 60947 - Part 4 and shall comprise:

- Fused combination unit (disconnector and fuse switch) or moulded case circuit breaker (AC23 minimum utilisation category).
- AC contactor (AC3 minimum utilisation category).

All motor starters associated with a turbine generator 'unit' shall be located in a single Motor Control Centre dedicated to that unit. The Motor Control Centre may be a separate cubicle within the Unit PLC panel.

The operating mechanism of the isolating device shall be mounted on the front of the cubicle, operated by a pistol grip type handle. The mechanism shall be interlocked with the door to prevent opening when in the on position. The mechanism shall be padlockable in the off position.

The rated operational current of the starter (Ie) shall be not less than the full-load current of the motor. The starter shall be rated for uninterruptible duty.

Thermal overload relays shall be Type 3c as defined in Clause 5.7.2 of IEC 60947-4-1. Time/current characteristics shall be supplied, by the manufacturer, on 28mm x 56mm logarithmic decades. These curves shall have a tolerance not exceeding + 10%.

Co-ordination of short circuit and overload protective devices shall be type 2 fully co-ordinated as defined in Clause 7.2.5 of IEC 60947-4-1 for a prospective short-circuit current not less than the value determined by the electrical system design. For this purpose the short circuit protection device shall be fitted with the maximum rating of motor circuit fuse.

Motor starters shall be suitable for both automatic and non-automatic methods of control.

Unless otherwise specified, motor starter control circuits shall be operated from a 230V AC supply, taken from the incoming supply to each motor starter cell, via a suitably rated MCB. All control and indication circuits between the motor starter cell and remote equipment (eg Unit PLC panels etc), must use 110V DC and suitably rated interposing relays to interface with the starter 230V AC controls shall be provided in the motor starter cell.

Power factor correction capacitors shall be provided in motor starters to correct the motor power factor to a minimum of 0.93. Separate contactors shall be used to switch the motor circuit and power factor correction equipment.

Where assisted start motor starters are required in order to reduce motor starting currents, electronic soft start units shall be used. Electronic soft start units shall be provided complete with bypass contactor. Assisted start operation shall be automatic changeover with adjustable time delays to suit the motor conditions.

Contactors shall be provided with auxiliary contacts to provide all required control and signalling functions and shall be provided with two additional spare normally open and two spare normally closed contacts.
Each starter shall be provided with the following local controls and indications as a minimum:-

- Supply Isolator.
- Running lamp.
- Stopped lamp.
- Fault lamp.
- Run/off/auto selector switch,

Each starter shall have the following interfaces with the Plant control system
- Motor Run - DI.
- Motor Auto - DI.
- Motor Fault - DI.
- Motor Start – DO
- Motor Stop DO

2.4.11.7.10 Relays

All relays are to be of best quality with contacts rated for a continuous duty of not less than 10A at 110V DC. They shall be encased in hermetically sealed enclosures and shall be free from discernible noise when energised. Auxiliary contacts are to be self-cleaning.

2.4.11.7.11 Isolators

All electrical panels, including motor control centers and distribution boards, must have an isolation switch on the incoming supply to comply with the AS/NZS3000 isolation requirements.

Any panel that is supplied from more than one 240/415V source must have a danger label affixed to the front warning that the panel is supplied from X sources and identifying the location of each of the sources.

All live side terminals of these isolators shall be shrouded to prevent accidental contact.

Isolators shall be rated for the continuous load current and for the maximum fault duty, which may be reached. Isolators shall not be smaller than sizes shown on the drawings.

Isolators shall be capable of being locked in the open or closed position. Isolators shall comply with IEC 60947-3 for AC 23 duty.

2.4.11.7.12 Pushbuttons and Pushbutton Switches

Pushbuttons and pushbutton switches shall be heavy-duty, oil-tight, complete with engraved legend plates, operators, and contact blocks. Legend plate engravings shall be selected by the Contractor and will be subject to the Project Manager's approval.

2.4.11.7.13 Contact Ratings

- Maximum Design Voltage. 500/300-V AC and 110-V DC.
- Continuous Current. 10-A AC or DC.
- Maximum Interrupting Current, Inductive. 3-A at 240-V AC and 2.2-A at 110-V DC.
- Maximum Making Current, Inductive. 30-A at 240-V AC and 2.2-A at 110-V DC.

2.4.11.7.14 Control and Selector Switches

Control and selector switches shall be heavy-duty, rotary type complying with the requirements of IEC 60947-5-1 for AC 11 duty.

Ratings

Maximum Design Voltage.	500/300-V AC and 240-V DC.
Continuous Current.	10-A AC or DC.
Maximum Interrupting Current, Inductive.	3-A at 240-V AC and 2.2-A at 110-V DC.
Maximum Making Current, Inductive.	30-A at 240-V AC and 2.2-A at 110-V DC.

Each switch shall be provided with an escutcheon plate clearly marked to show each operating position. Escutcheon plate markings shall be selected by the Contractor and will be subject to the Project Manager's approval.

The type and colour of the switch handle shall be selected by the Contractor and will be subject to the Project Manager's approval.

2.4.11.7.15 Test Blocks

Plug type test blocks shall be provided on all protection circuits for testing CT, CT and trip circuits.

2.4.11.7.16 Electrical Digital and Analogue Indicating Instruments

Instruments shall be of the flush mounting type with non-reflecting glass. They shall be calibrated and suitable for the application. Electrical measuring instruments generally shall be 96 x 96 mm but may be 72 x 72 mm if approved by the Project Manager. Analogue instruments shall be of the 270° full-scale deflection type.
Digital instruments shall have the following features:

- Bright orange LED display.
- Minimum 4-digit, 12 mm-high, readout.
- Black bezel with hardware and accessories for front-of-panel mounting.
- 1% accuracy

Indicating instruments shall conform to IEC 60051, class index 1.5.
Scale markings shall be selected by the Contractor and will be subject to the Project Manager's approval. Where instruments are connected to instrument transformer secondaries, the scale markings shall be selected to read the electrical quantities on the transformer primary.

2.4.11.7.17 Transducers and Transmitters

Transducers and transmitters shall be suitable for accurately measuring the specified quantities. Outputs shall be a dc current signal ranging from 4 to 20-mA full scale, suitable for termination in a load resistance up to 750Ω.

Unless specified otherwise, the maximum allowable error shall not exceed ±0.25% of full scale at 25°C, and the error resulting from a temperature variation between -20°C and 60°C shall not exceed ±0.5% of full scale. AC output ripple shall not exceed 1%. The units shall be provided with a 10% full scale calibration adjustment, and the response time shall be 400 ms or better from 0 to 99%. There shall be electrical isolation between input, output, external power supply if used, and the case ground connection. All transducers and transmitters shall have a dielectric test voltage rating conforming to IEC SWC test requirements.

2.4.11.7.18 Indicating Lamps

Lamps shall be light emitting diode (led) type, 22.5mm diameter with press to test facility.
The indicating lamps and resistors shall be rated to operate at 240-V AC or 110-V DC.

2.4.11.7.19 Heaters

Enclosures containing electrical control and switching equipment shall be equipped with electric space heaters for moisture control. The construction of the enclosures and the placement of the heaters shall assure effective circulation of air and prevent damage to equipment by overheating. Heaters shall be rated 240-V AC, single-phase. They shall be provided with thermostatically operated controls with "on-off" switches mounted inside the enclosure.

2.4.11.7.20 Lighting and Receptacles

Enclosures larger than 1.0 m^2 (vertical, front-of-panel surface area) shall be provided with a light and receptacle inside the enclosure to facilitate operation and maintenance. The light shall be incandescent type, with wire-guard and "on-off" switch. The receptacle shall be a duplex type, 2-

pole, 3-wire. Power supply to the light and receptacle will be from a single-phase, 240-V AC, circuit.

2.4.11.7.21 Panel Wiring

All panel wiring shall be carried out in a neat and systematic manner with cable supported clear of the panels and other surfaces at all points to obtain free circulation of air.

All PVC insulated panel wiring shall comply with the requirements of BS 6231 Type BK. Conductors shall generally have a minimum cross section equivalent to 3/0.77mm (1.5mm²), 7/0.67mm (2.5mm²) but single stranded conductors should only be employed for rigid connections which are not subject to movement or vibration during shipment, operation or maintenance.

The Contractor shall propose a panel wire colour system to be used and shall submit to the Project Manager for approval. The colour system adopted must clearly:-

- Use different colours for 230/400V AC phase and neutral conductor.
- Differentiate 110V DC positive and negative conductors.
- Clearly identify RTD and analogue signal conductors.
- Green and Green/Yellow insulation may only be used for earthing conductors.

Wiring to doors shall be anchored at the panel side and sufficient length shall be provided to enable the door to swing fully open without strain on cabling.

All panel wiring shall be number ferruled using slide on cable markers with indelible markings. Wiring systems that rely on terminal number identification only are prohibited.

All outgoing control / controlled field wiring shall be brought out to terminals to facilitate ease of termination. Termination of all wiring at these terminals shall be effected using pre-insulated crimped ferrules or lugs of the correct size to suit cable and terminal capacity. Segregation shall be provided between 400/230V AC, 110V DC signal, 110V control and RTD/analogue terminals. No wires may be teed or jointed between terminal points.

Bus wiring between adjacent panels, cubicles, etc, shall be terminated in each panel, with cables used for the interconnection. The use of panel wiring between adjacent cubicles not permitted

2.4.11.7.22 Panel Earthing

All metallic cases of instruments, control switches, relays, etc, mounted in panels, steel or otherwise, shall be connected by means of green with yellow stripes PVC insulated copper conductors of not less than 2.5mm² cross section to the nearest earth bar.
All metalwork shall be bonded to the main earth bar. All hinged panels shall be bonded with flexible copper.

All cable sheaths and earthing conductors shall be bonded to the earth bar. Use compression type conductor lugs for all earth connections with bolted joints. Ensure that all connections are tightened.
Earth continuity shall not depend upon metal joints. For panel earthing use starred washers between screw and panel.

2.4.11.7.23 Panel Labelling

All panels shall be fitted with an identification/rating plate displaying the following information: site name; rated voltage, phasing, frequency, current, etc; panel/equipment manufacturer; and contract number.
Labels shall consist of white lettering engraved on black traffolyte. Lettering shall be 12 mm high for main panel labels and 5 mm high for circuit descriptive labels. All labels shall be fixed with chromium plated or stainless steel screws.

The requirement for labels includes, but is not limited to, the following:

- All switchboards, panels, boxes, cabinets, cubicles or enclosures.
- Equipment mounted in or on the above items including relays, contactors, starters, sounders, motors, switches, sockets, controllers and luminaires.

2.4.11.8 Quality Control Requirements

2.4.11.8.1 Factory Tests

Each item of equipment and all similar equipment supplied as spare parts shall be given the manufacturer's routine factory tests to ensure successful operation of all parts of the assemblies. Factory tests shall include all routine tests required by the relevant IEC Standard. Test equipment and test methods (including equipment calibration and certification) shall conform to the applicable requirements of the test standard.

Operational tests shall be performed on all of the equipment or devices insofar as practicable to demonstrate that they function properly. Adjustable devices shall be checked for range of adjustment and given final adjustment, insofar as possible, in the shop.
Insulation resistance and voltage withstand tests in accordance with applicable provisions of the IEC standards shall be undertaken on all electrical circuits including control, instrument and protection circuits.

2.4.11.8.2 Field Tests

The equipment shall be installed, field tested and placed in operation by the Contractor as directed by the manufacturer's supervising erectors and test engineers. All necessary assistance, tools, and facilities required for the supervising erectors and test engineers shall be provided.

Field tests shall include all routine field tests required by the relevant Australian/New Zealand and/or IEC Standards.

Prior to watering the turbines, operational tests shall be performed on all of the equipment or devices insofar as practicable to demonstrate that they function properly. Adjustable devices shall be checked for range of adjustment and final settings applied.

2.4.12 22kV Switchgear

2.4.12.1 General Requirements

The switchgear shall be an extensible, metal clad, metal enclosed single busbar design and construction. Relevant standards as indicated shall be used for the construction, design and testing of the switchboard as a whole and of individual components. The switchgear shall be suitable for the site electrical conditions for the relevant voltage as indicated. Each cubicle shall form a completely self contained sub unit of the board with space for all high and low voltage components.

Separate compartments shall be provided for:-

- busbars
- cable terminations
- circuit breaker
- control panel

Compartments shall provide protection against contact with live equipment both between each other and from the outside of the cubicle. The standard of protection shall be IP21 as described in IEC 60529.
Provision shall be made to enable high voltage tests to be carried out on a cable via the circuit contacts. Facilities shall be provided to allow primary injection testing of CTs and secondary injection testing of protection relays by means of plug-in test facilities.

2.4.12.2 Busbars

The switchgear shall have a 3-phase, 3-conductor bus with a continuous current-carrying capacity of at least 630 A with a hottest-spot temperature rise not greater than 65°C above the ambient temperature outside the switchgear.

Buses and connections shall be fully insulated for 22-kV service with flame-retardant sleeve-type or moulded insulating material. The momentary current rating of all buses and connections shall be no less than 12.5kA rms asymmetrical.

A ground bus shall extend through the entire length of the switchgear. The switchgear frame and all internal equipment bases and mountings shall be connected to the ground bus.

A bus earth switch, interlocked to the generator and incoming circuit breakers, shall be provided.

2.4.12.3 Circuit Breakers

2.4.12.3.1. General

The circuit breakers shall be 3-pole, indoor vacuum or SF6 type, having disconnecting means as an integral part of the removable draw-out unit. The frame of the breaker shall be equipped with wheels.

The cubicles for the draw-out circuit breakers shall have self-engaging definite-positioning stops for "Disconnected," "Test," and "Connected" positions.
Circuit breakers shall be furnished with auxiliary contacts on the breaker draw-out unit for control and indication.

Provision shall be made to ensure that the breaker cannot be withdrawn or inserted without being open.

Generator 22kV circuit breakers shall have the capability to earth the generator windings during maintenance.

The breakers shall be equipped with a 110-V DC shunt trip coil and a stored-energy closing mechanism, which is charged by a 110-V DC motor.

Equipment required to remove the breakers such as cranks, lifting levers, moving dollies, etc. shall be supplied as part of this equipment
.
The breaker compartment shall include indicating lights and control wiring to give a red indication for breaker closed position and a green indication for breaker open position.

Indication shall be visible from the front with door closed at all times when the circuit breaker is within the housing. The red indicating light shall be wired so as to provide a continuous indication of the continuity of the shunt trip circuit when the breaker is closed.

The circuit breaker shall be provided with an operation counter, a local control switch, and a "Local/Remote" selector switch. A cell switch to provide remote indication when the removable element is withdrawn shall be furnished.

2.4.12.3.2. Ratings

Circuit breaker rating shall be as follows:

Voltage (nominal)	22kV
Maximum Continuous System Voltage	24kV
Rated short time withstand current (nominal)	12.5kA
Rated peak withstand current	40kA
Withstand test voltages:	
- 50-Hz, not less than	50 kV
- Basic impulse, not less than	125 kV
Rated continuous current	630 A rms
Rated Interrupting time, cycles	5 cycles

2.4.12.4 Instrument Transformers

2.4.12.4.1. General

The instrument transformers shall be indoor type designed and rated in accordance with IEC60185 or 60186.

Voltage Transformers

22kV voltage transformers shall be manufactured to IEC60186 and shall have a winding ratio of 22kV/√3:110/√3. Three phase voltage transformers shall comprise three individual single phase transformers, each of cast resin type.

Voltage transformers shall have a standard insulation class of 22kV and a basic impulse insulation level of not less than 125 kV.

The IEC relaying accuracy class at 50-Hz shall be at least 3P for protective circuits and class 1.0 for measuring or metering circuits.

Each transformer shall be equipped with the necessary mounting devices, fuse blocks, and 2 removable, insulated, primary current limiting fuses. The fuses shall be able to withstand the maximum possible energizing current but shall interrupt the circuit in case of a short circuit on the secondaries of the voltage transformers.

The voltage transformers shall be of the draw-out type with disconnecting devices so that the high-voltage terminals of the potential transformers are disconnected and grounded and the secondaries disconnected when the transformer is in the withdrawn position. Shutters that are closed when the potential transformer is withdrawn shall be provided.

2.4.12.4.2. Current Transformers

Current transformers shall be manufactured to IEC60185 and shall use standard IEC winding ratio's. Protection and instrumentation current transformers shall use 1 A secondary and metering transformers 5A secondary. Current transformers shall have a standard insulation class of 22 kV and a basic impulse insulation level of not less than 125 kV and shall be cast resin type of either ring or bar configuration.

The IEC relaying accuracy class at 50-Hz shall be at least 5P20 for protective circuits and class 0.2 for measuring or metering circuits.

Standard application data shall be furnished in accordance with IEC 60185. Curves and data to be furnished for the transformers shall include, but not be limited to the following:

- Ratio and phase-angle correction curves.
- Short-time thermal and dynamic stability current ratings.
- Excitation current curves showing "knee" point voltage for each type and rating.

Current transformers shall be provided on the circuit breakers as listed herein.

Protection CTs

- Ratio 630/400/200/1A
- Number of three phase sets required Two

- Accuracy Class 5P20

Metering CTs

- Ratio 630/400/200/5A
- Number of three phase sets required One
- Accuracy Class 0.2

2.4.12.4.3. Surge Protection Equipment

Surge protection shall be provided on each generator circuit breaker. Each set of surge protection equipment shall consist of 3 surge arresters and 3 surge capacitors mounted in a separate compartment of the switchgear assembly.

Surge arresters shall be of the metal oxide station class type for rotating AC machines, suitable for surge protection of 22.0 kV, 3-phase, 50-Hz, high resistance-grounded generators. The surge arresters shall meet the requirements of the appropriate IEC or ANSI/IEEE Standards. One arrester shall be connected between each generator phase conductor and the switchgear ground bus.

2.4.12.4.4. Cable Terminators

HV cable entry shall be from the top or bottom via removable gland plates. The gland plates shall be made of non-magnetic metal. The gland plates shall completely seal off the bottom of the cable termination panel and shall be bonded to the associated cubicle to provide earth continuity.

Control and instrumentation cable and AC / DC power cables shall be wired between panels and marshalled at a single termination point at the switchboard. The boxes shall be suitable for termination of a single or a number of multicore control and or power low voltage cables.

Each cable box shall be provided with two earth terminals per phase for the following purposes:-

- The separate earthing of the copper wire screen of each cable.
- The temporary earthing of the cable terminal.
- The temporary earthing of the bushing terminal.

2.4.12.4.5. Control Switches

Control switch for each circuit breaker control shall be 3-position, momentary-contact type, with spring return to the neutral position, and shall have a pistol-grip handle. A pull-to-lock feature shall be provided.

Selector switch for local/remote control shall be 2-position, maintained contact type and shall have a round notched handle.

2.4.12.4.6. Protective Relaying

All protection required for the units shall be mounted on the Unit Control, and protection panels. Refer Section 2.4.99 Protective Relays.

2.4.12.4.7. Multifunction Metering Modules

A multifunction metering module shall be provided on the control cubicle for each circuit breaker. The multifunction meter modules shall be a digital instrumentation package consisting of the following:

Drawings

- Upolu EPC Map
- Taelefaga Geographical Map

Supplementary Information

- Limited information on the existing generators at Taelefaga.
- IEE for Taelefaga Third Generator

5.1 Form of Completion Certificate

Contract: [. . . . *insert name of contract and contract identification details*. . . . .]

Date: .....

Certificate No.: .....

To: [. . . . *insert name and address of contractor*. . . . .]

Dear Ladies and/or Gentlemen,

Pursuant to GCC Clause 24 (Completion of the Facilities) of the General Conditions of the Contract entered into between yourselves and the Employer dated [. . . . *insert date*. . . . .], relating to the [. . . *brief description of the Facilities* . . . .], we hereby notify you that the following part(s) of the Facilities was (were) complete on the date specified below, and that, in accordance with the terms of the Contract, the Employer hereby takes over the said part(s) of the Facilities, together with the responsibility for care and custody and the risk of loss thereof on the date mentioned below.

1. Description of the Facilities or part thereof: [. . . *description* . . . .]

2. Date of Completion: [. . . *date* . . . .]

However, you are required to complete the outstanding items listed in the attachment hereto as soon as practicable.

This letter does not relieve you of your obligation to complete the execution of the Facilities in accordance with the Contract nor of your obligations during the Defect Liability Period.

Very truly yours,

[. . . *Signature* . . . .]

Project Manager

5.2 Form of Operational Acceptance Certificate

Contract: [. . . . .*insert name of contract and contract identification details*. . . . .]

Date: .....

Certificate No.: .....

To: [. . . . .*insert name and address of contractor*. . . . .]

Pursuant to GCC Subclause 25.3 (Operational Acceptance) of the General Conditions of the Contract entered into between yourselves and the Employer dated [. . .*date*. . .], relating to the [. . .*brief description of the facilities*. . .], we hereby notify you that the Functional Guarantees of the following part(s) of the Facilities were satisfactorily attained on the date specified below.

1. Description of the Facilities or part thereof: [. . . *description* . . .]

2. Date of Operational Acceptance: [. . . *date* . . .]

This letter does not relieve you of your obligation to complete the execution of the Facilities in accordance with the Contract nor of your obligations during the Defect Liability Period.

Very truly yours,

[. . . .*Signature* . . . .]

Project Manager

6. Change Orders

6.1 Change Order Procedure

6.1.1 General
6.1.2 Change Order Log
6.1.3 References for Changes

6.2. Change Order Forms

6.2.1 Request for Change Proposal
6.2.2 Estimate for Change Proposal
6.2.3 Acceptance of Estimate
6.2.4 Change Proposal
6.2.5 Change Order
6.2.6 Pending Agreement Change Order
6.2.7 Application for Change Proposal

6.1. Change Order Procedure

6.1.1 General

This section provides samples of procedures and forms for implementing changes in the Facilities during the performance of the Contract in accordance with GCC Clause 39 (Change in the Facilities) of the General Conditions.

6.1.2 Change Order Log

The Contractor shall keep an up-to-date Change Order Log to show the current status of Requests for Change and Changes authorized or pending. Entries of the Changes in the Change Order Log shall be made to ensure that the log is up-to-date. The Contractor shall attach a copy of the current Change Order Log in the monthly progress report to be submitted to the Employer.

6.1.3 References for Changes

(1) Request for Change as referred to in GCC Clause 39 shall be serially numbered CR-X-nnn.

(2) Estimate for Change Proposal as referred to in GCC Clause 39 shall be serially numbered CN-X-nnn.

(3) Acceptance of Estimate as referred to in GCC Clause 39 shall be serially numbered CA-X-nnn.

(4) Change Proposal as referred to in GCC Clause 39 shall be serially numbered CP-X-nnn.

(5) Change Order as referred to in GCC Clause 39 shall be serially numbered CO-X-nnn.

Note:

(a) Requests for Change issued from the Employer's Home Office and the Site representatives of the Employer shall have the following respective references:

Home Office	CR-H-nnn
Site	CR-S-nnn

(b) The above number "nnn" is the same for Request for Change, Estimate for Change Proposal, Acceptance of Estimate, Change Proposal and Change Order.

6.2 Change Order Forms

6.2.1 Request for Change Proposal Form

[*Employer's letterhead*]

To: [*Contractor's name and address*] Date:

Attention: [*Name and title*]

Contract Name: [*Contract name*]
Contract Number: [*Contract number*]

Dear Ladies and/or Gentlemen:

With reference to the captioned Contract, you are requested to prepare and submit a Change Proposal for the Change noted below in accordance with the following instructions within [*number*] days of the date of this letter [or on or before (*date*)].

1. Title of Change: [*Title*]
2. Change Request No./Rev.: [*Number*]
3. Originator of Change:
   Employer: [Name]
   Contractor (by Application for Change Proposal No. [Number Refer to Annex 6.2.7])
4. Brief Description of Change: [*Description*]
5. Facilities and/or Item No. of equipment related to the requested Change: [*Description*]
6. Reference drawings and/or technical documents for the request of Change:
   Drawing No./Document No. *Description*
7. Detailed conditions or special requirements on the requested Change: [*Description*]
8. General Terms and Conditions:
   (a) Please submit your estimate showing what effect the requested Change will have on the Contract Price.
   (b) Your estimate shall include your claim for the additional time, if any, for completing the requested Change.
   (c) If you have any opinion that is critical to the adoption of the requested Change in connection with the conformability to the other provisions of the Contract or the safety of the Plant or Facilities, please inform us in your proposal of revised provisions.
   (d) Any increase or decrease in the work of the Contractor relating to the services of its personnel shall be calculated.
   (e) You shall not proceed with the execution of the work for the requested Change until we have accepted and confirmed the amount and nature in writing.

[*Employer's name*]
[*Signature*]
[*Name of signatory*]
[*Title of signatory*]

6.2.2 Estimate for Change Proposal Form

[*Contractor's letterhead*]

To: [*Employer's name and address*] Date:

Attention: [*Name and title*]

Contract Name: [*Contract name*]
Contract Number: [*Contract number*]

Dear Ladies and/or Gentlemen:

With reference to your Request for Change Proposal, we are pleased to notify you of the approximate cost to prepare the below-referenced Change Proposal in accordance with GCC Subclause 39.2.1 of the General Conditions. We acknowledge that your agreement to the cost of preparing the Change Proposal, in accordance with GCC Subclause 39.2.2, is required before estimating the cost for change work.

1. Title of Change: [*Title*]
2. Change Request No./Rev.: [*Number*]
3. Brief Description of Change: [*Description*]
4. Scheduled Impact of Change: [*Description*]
5. Cost for Preparation of Change Proposal: [*insert costs, which shall be in the currencies of the contract*]

(a)	Engineering		(Amount)
	(i) Engineer	_____ hours (hrs) x _____ rate/hr =	_____
	(ii) Draftsperson	_____ hrs x _____ rate/hr =	_____
	Sub-total	_____ hrs	_____
	Total Engineering Cost		_____
(b)	Other Cost		_____
	Total Cost (a) + (b)		_____

[*Contractor's name*]
[*Signature*]
[*Name of signatory*]
[*Title of signatory*]

6.2.3 Acceptance of Estimate Form

[*Employer's letterhead*]

To: [*Contractor's name and address*] Date:

Attention: *[Name and title]*

Contract Name: *[Contract name]*
Contract Number: *[Contract number]*

Dear Ladies and/or Gentlemen:

We hereby accept your Estimate for Change Proposal and agree that you should proceed with the preparation of the Change Proposal.

1. Title of Change: [*Title*]
2. Change Request No./Rev.: [*Request number/revision*]
3. Estimate for Change Proposal No./Rev.: [*Proposal number/revision*]
4. Acceptance of Estimate No./Rev.: [*Estimate number/revision*]
5. Brief Description of Change: [*Description*]
6. Other Terms and Conditions: In the event that we decide not to order the Change accepted, you shall be entitled to compensation for the cost of preparing the Change Proposal described in your Estimate for Change Proposal mentioned in para. 3 above in accordance with GCC Clause 39 of the General Conditions.

[*Employer's name*]
[*Signature*]
[*Name of signatory*]
[*Title of signatory*]

6.2.4 Change Proposal Form

[*Contractor's letterhead*]

To: [*Employer's name and address*] Date:

Attention: [*Name and title*]

Contract Name: [*Contract name*]
Contract Number: [*Contract number*]

Dear Ladies and/or Gentlemen:

In response to your Request for Change Proposal No. [Number], we hereby submit our proposal as follows:

1. Title of Change: [*Name*]
2. Change Proposal No./Rev.: [*Proposal number / revision*]
3. Originator of Change: Employer: [*Name*] / Contractor: [*Name*]
4. Brief Description of Change: [*Description*]
5. Reasons for Change: [*Reason*]
6. Facilities and/or Item No. of Equipment related to the requested Change: [*Facilities*]
7. Reference drawings and/or technical documents for the requested Change:
   [*Drawing/Document No./Description*]
8. Estimate of increase/decrease to the Contract Price resulting from the Change Proposal:

		Amount [*insert amounts in the currencies of the Contract*]
(a)	Direct material	_____
(b)	Major construction equipment	_____
(c)	Direct field labor (Total hrs)	_____
(d)	Subcontracts	_____
(e)	Indirect material and labor	_____
(f)	Site supervision	_____
(g)	Head office technical staff salaries	
	Process engineer _____ hrs @ _____ rate/hr	_____
	Project engineer _____ hrs @ _____ rate/hr	_____
	Equipment engineer _____ hrs @ _____ rate/hr	_____
	Procurement _____ hrs @ _____ rate/hr	_____
	Draftsperson _____ hrs @ _____ rate/hr	_____
	Total _____ hrs	

(h) Extraordinary costs (computer, travel, etc.) _____

(i) Fee for general administration, % of Items _____

(j) Taxes and customs duties _____

Total lump sum cost of Change Proposal [*Sum of items (a) to (j)*]

Cost to prepare Estimate for Change Proposal [*Amount payable if Change is not accepted*]

9. Additional time for Completion required due to Change Proposal
10. Effect on the Functional Guarantees
11. Effect on the other terms and conditions of the Contract
12. Validity of this Proposal: within [Number] days after receipt of this Proposal by the Employer
13. Other terms and conditions of this Change Proposal:
    (a) You are requested to notify us of your acceptance, comments or rejection of this detailed Change Proposal within [Number] days from your receipt of this Proposal.
    (b) The amount of any increase and/or decrease shall be taken into account in the adjustment of the Contract Price.
    (c) Contractor's cost for preparation of this Change Proposal: [*. . . .insert amount. This cost shall be reimbursed by the employer in case of employer's withdrawal or rejection of this Change Proposal without default of the contractor in accordance with GCC Clause 39 of the General Conditions . . . .*]

[*Contractor's name*]
[*Signature*]
[*Name of signatory*]
[*Title of signatory*]

6.2.5 Change Order Form

[*Employer's letterhead*]

To: *[Contractor's name and address]* Date:

Attention: *[Name and title]*

Contract Name: *[Contract name]*
Contract Number: *[Contract number]*

Dear Ladies and/or Gentlemen:

We approve the Change Order for the work specified in the Change Proposal (No. [*number*]), and agree to adjust the Contract Price, Time for Completion, and/or other conditions of the Contract in accordance with GCC Clause 39 of the General Conditions.

1. Title of Change: [*Name*]
2. Change Request No./Rev.: [*Request number / revision*]
3. Change Order No./Rev.: [*Order number / revision*]
4. Originator of Change: Employer: [*Name*] / Contractor: [*Name*]
5. Authorized Price:
   Ref. No.: [*Number*] Date: [*Date*]
   Foreign currency portion [*Amount*] plus Local currency portion [*Amount*]
6. Adjustment of Time for Completion
   None Increase [*Number*] days Decrease [*Number*] days
7. Other effects, if any

Authorized by: _____ Date: _____
Employer

Accepted by: _____ Date: _____
Contractor

6.2.6 Pending Agreement Change Order Form

[*Employer's letterhead*]

To: *[Contractor's name and address]* Date:

Attention: *[Name and title]*

Contract Name: *[Contract name]*
Contract Number: *[Contract number]*

Dear Ladies and/or Gentlemen:

We instruct you to carry out the work in the Change Order detailed below in accordance with GCC Clause 39 of the General Conditions.

1. Title of Change: [*Name*]
2. Employer's Request for Change Proposal No./Rev.: [*number/revision*] dated: [*date*]
3. Contractor's Change Proposal No./Rev.: [*number / revision*] dated: [*date*]
4. Brief Description of Change: [*Description*]
5. Facilities and/or Item No. of equipment related to the requested Change: [*Facilities*]
6. Reference Drawings and/or technical documents for the requested Change:
   [*Drawing / Document No. / Description*]
7. Adjustment of Time for Completion:
8. Other change in the Contract terms:
9. Other terms and conditions:

[*Employer's name*]

[*Signature*]

[*Name of signatory*]

[*Title of signatory*]

6.2.7 Application for Change Proposal Form

[*Contractor's letterhead*]

To: [*Employer's name and address*] Date:

Attention: [*Name and title*]

Contract Name: [*Contract name*]
Contract Number: [*Contract number*]

Dear Ladies and/or Gentlemen:

We hereby propose that the work mentioned below be treated as a Change in the Facilities.

1. Title of Change: [*Name*]
2. Application for Change Proposal No./Rev.: [*Number / revision*] dated: [*Date*]
3. Brief Description of Change: [*Description*]
4. Reasons for Change:
5. Order of Magnitude Estimation (amount in the currencies of the Contract): [*Amount*]
6. Scheduled Impact of Change:
7. Effect on Functional Guarantees, if any:
8. Appendix:

[*Contractor's name*]

[*Signature*]

[*Name of signatory*]

[*Title of signatory*]

7. Personnel Requirements

Using Form PER-1 and PER-2 in Section 4 (Bidding Forms), the Bidder must demonstrate that it has personnel who meet the following requirements:

requirements:

No.	*Position*	Total Work Experience [years]	Experience In Similar Work [years]
1	Project Manager	10	5
2	Hydro Governor and Control System Engineer	10	8
3	.Hydro Power Electrical Engineer	10	8
4	Transmission Electrical Engineer for installation, testing and commissioning of large transformers	8	3
5	Commissioning Engineer for Hydro Electricals	10	5

The Bidder shall provide details of the proposed personnel and their experience records in the relevant Information Forms included in Section 4 (Bidding Forms).

8. Equipment Requirements

Using Form EQU in Section 4 (Bidding Forms), the Bidder must demonstrate that it has the key equipment listed below:

No.	Equipment Type and Characteristics	Minimum Number Required
1		
2		
3		
4		
5		