



**Da Afghanistan Breshna Sherkat (DABS)**  
**Directorate of Program Management Office (DPMO)**  
**World Bank Project Implementation Unit (PIU-WB)**  
**Mahipar Hydropower plant unit 1 Rehabilitation Project (MHPP)**

# **Employer's Requirements for Mahipar Hydropower Plant MHPP Rehabilitation, Replacement and Overhauling and**

**JAN-2024**



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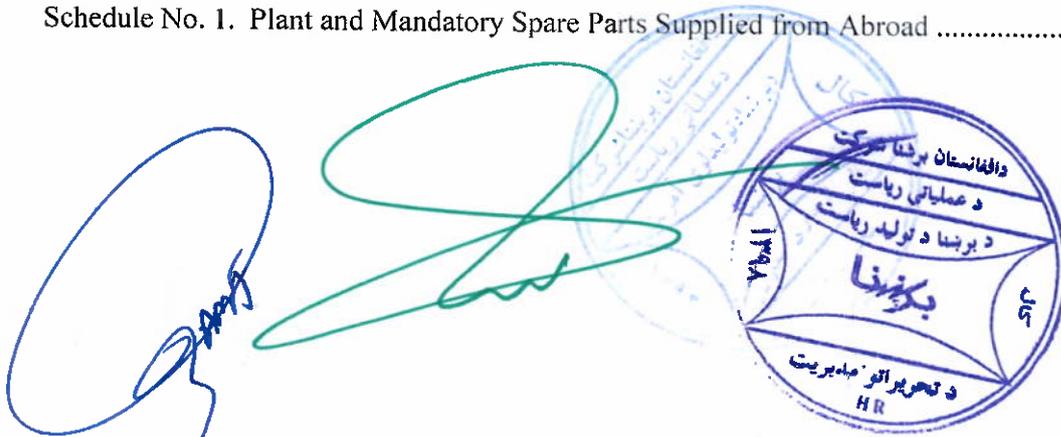
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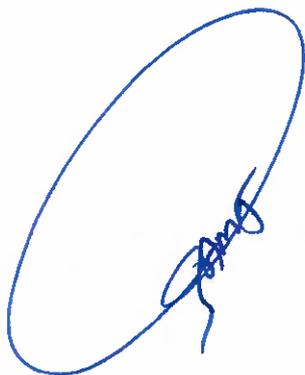




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## Chapter 1 – Employer's Requirements

### 1. Background

Mahipar hydroelectric power plant MHPP is run of river hydro power plant located at Kabul River in Mahipar of Sorobi district, 30 km East of Kabul on Kabul-Jalalabad Road, Afghanistan. Location coordinates are: Latitude= 34.556, Longitude= 69.4787. This infrastructure is Hydro Power Plant with a design capacity of 66 MW. It has 3 units, which installed and commissioned by VOITH Siemens in 1967.

### 2. General Rehabilitation, Replacement and Overhauling of Mahipar Hydropower Plant unit # 1:

The Mahipar hydro power needs rehabilitation, overhauling and replacement of some parts, as the plant is working for time of services. Although it's still in working condition but some parts are need to be rehabilitate, overhaul and replace to ensuring the continuous normal functionality of the power plant for long period.

Indeed, some parts of the mechanical, electrical and hydro mechanical of the power plant has been running for more than over the inter repair time, since the last repairing. At the time of rehabilitation and overhauling, more precise diagnostic services are required also some parts of the plant unit # 1 need to be replace, changed and need for reverse engineering. Bidders Contractor is required to prepare a refined comprehensive plan and schedule for the rehabilitation, replacing, reverse engineering and overhauling of the power plant unit # 1 for bringing the plant in a functional form.

The works include the rehabilitation, replacement, changing, repairing, reverse engineering and overhauling including disassembly, reassembly, adjustment, testing, pre commissioning, commissioning, trial operation and verification of operating parameters and return to full functional and operational condition of all mechanical, hydro mechanical and electrical sections.

#### 2.1 Rehabilitation

The scope of works include the completion of the rehabilitation works for Mahipar hydropower plant unit # 1 including disassembly of generators, turbines and power plant unit # 1 accessories for diagnostic, straightness verification test at Mahipar site, some parts repair, if require, reassembly of generator and turbine to perform the testing of control system, adjustment and calibration of unit # 1 testing the complete unit after reassembly, trail operation and verification of operating parameters and return to full functional and operational service.

- Prepare a comprehensive plan and schedule for the complete rehabilitation for bringing the unit # 1 in a functional form.
- Survey the works site to assess the works carried out so far and to update the current status of unit # 1.



- Carrying out a verification test of unit # 1 equipment as a pre diagnostics activity through a latest high accuracy machine to establish a fact that proper functioned or not. If the result is positive than, replacing the equipment otherwise must be repaired.
- Disassembly of the generator along with turbine and re-installation.
- Reassembly of the complete generator and turbine.
- Carrying out the pre-commissioning and commissioning of unit 1.
- Carrying out all necessary adjustments, calibration testing etc. of control systems and equipment for the satisfactory operation of the unit 1.
- Carrying out trial operation of unit # 1 to be witnessed by the Employer and the Project Manager.
- Measure and verify the performance and functional capacity of rehabilitated unit through set international standards for operational testing.

## 2.2 Overhauling

The unit # 1 of Mahipar hydro power plant it's some parts needs overhauling as it's still in working condition but overhaul exercise will be ensuring the continuous functionality of unit # 1 for another period of time. Diagnostics services are required for the overhaul some parts of turbine generator as this unit have been running over the inter repair time.

The works include the overhauling of unit # 1 including disassembly, reassembly, adjustment, testing the complete unit # 1, trial operation, pre-commissioning, commissioning and verification of operating parameters and return to full functional and operational condition. During this overhauling, the unit # 1 is to be stripped off and all the defective/worn out parts/ components repaired/ replaced with new ones. Then the unit is re-commissioned as per originally established commission practice of the power plant. Contractor should prepare a comprehensive plan and schedule for the complete overhauling items which are mentioned in the turbine and generator sections, also bringing the unit in a functional form.

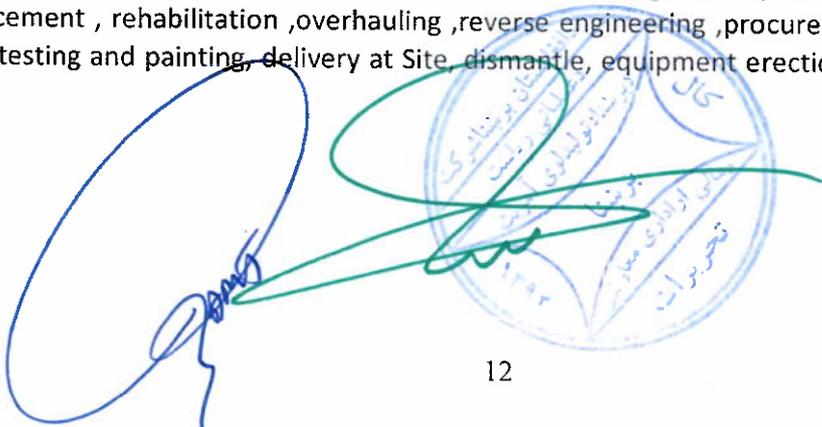
## 2.3 Replacement

The replacement parts of the power plant unit # 1 which is mentioned in this scope should be as per latest and modern technology, optimized design and well-matched with power plant requirement. The contractor should be considering the optimized modern design as per new technology and international recognized standard.

## 3. Technical Scope for Rehabilitation, Replacement and Overhauling

### 3.1 Electro mechanical facilities

The Electro-Mechanical to be executed under the Contract shall include the provision of plant unit # 1 and equipment as hereinafter outlined including, Goods, works and services for replacement , rehabilitation ,overhauling ,reverse engineering ,procurement, manufacture, shop testing and painting, delivery at Site, dismantle, equipment erection / installation and



painting at Site, Site Pre-Commissioning and commissioning also acceptance testing, defects liability of the systems, including any necessary accessories.

The scope shall include also the on-site training of Employer's operation and maintenance personnel. It is not intention of these specifications to specify any design detail. It is left to the experience and practice of the bidders, who shall furnish equipment which shall meet, in all aspects, the basic requirements as specified herein with regard to performance, durability and satisfactory operation.

Even if not specifically mentioned in these specifications, all accessories or apparatus which are usual or necessary to ensure safe and satisfactory operations, shall be considered as included in the works and shall be provided by the Contractor as a part of the works at no additional cost to the Employer. The Contractor shall coordinate requirements, ratings and characteristics of all equipment and systems to ensure that the complete installation shall work correctly and safely without causing harm to personnel and to new or existing equipment.

**3.2 Hydraulics turbines 16817 (J.M. VOITH) and auxiliaries:**

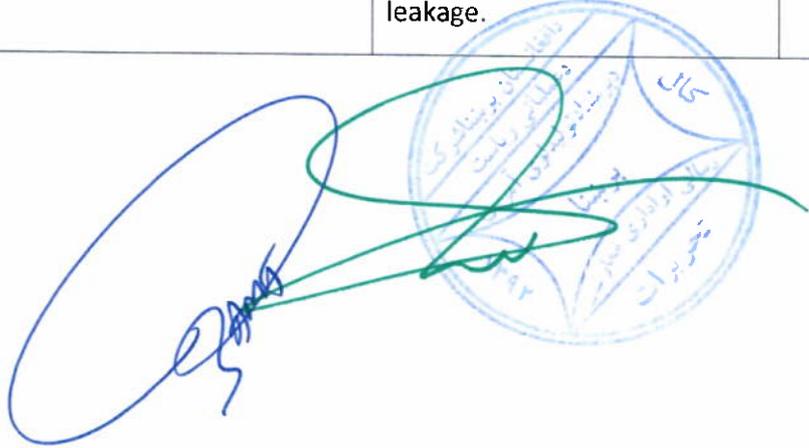
The Mahipar hydropower plant has three vertical shaft Francis type turbines manufactured, installed and commissioned in 1967 by Germany VOITH SIEMENS with a total installed capacity 66 MW that has been connected with local grid.

**Hydraulic turbine and auxiliaries:**

- Three vertical Francis type hydraulics turbine
- Three governing systems and accessories
- Three set of cooling water systems
- One lot of spare parts

The following table shows the technical status and scope of replacement, rehabilitation and overhauling for turbine sections.

Turbine # 1			
S.No	Description	Technical status	Choice of work
1	Shaft	Shafts are not functioning properly.	Unit # 1 turbine's shafts need to replace.
2	Turbine bearings	Bearing of turbines are eroded	Need to replace
3	Turbine shaft's seals	Turbine shaft's seals has oil leakage.	Need to replace



4	Runner with upper and lower labyrinths	Runner of the turbine has crack, cavities and lost the weight.	Need to replace
5	Foundation rings	Foundation rings of unit#1 is made by the plant maintenance personnel, but it is not in standard situation,	Foundation rings need to replace
6	Facing plate of bottom rings	Not in good condition	Need to replace
7	Facing plate of head covers	Not in good condition	Need to replace
8	Upper and lower labyrinths of head cover	Not in good condition	Need to replace
9	Oil pressure unit OPUs (24 bar systems)	Not in good condition	Need to replace
10	Protection, automation and governor systems of unit#1's MIV	Not in good condition	Need to replace
11	Bronze bushing of MIV	Not in good condition	Need to replace
12	Oil pumps systems for all units	Not in good condition	Need to replace
13	Turbine's MIV bypass systems	Not in good condition	Need to replace
14	Turbine filters for bronze and steel rings of unite#1	Not in good condition	Need to replace

15	Draft tubes and cones	Draft tube and cones of the power plant are made from Steel which are embedded in concrete.	Draft tubes and cones are need to be overhaul also the steel structure should be Cementing and concrete injected.
16	Spiral cases	From construction of the power plant still now the spiral case is not overhauled.	Overhauling is needed especially in the section which are faced with water.
17	Tailrace stop logs	Stop log rubber are damaged and not adjusting in their places during the time of turbine overhauling.	The systems should be repair and overhauled
18	Main inlet valve MIV	Due to duration of time and corrosion some parts are	Need to replace
18.1	Gate valve control		

18.2	Oil pressure systems of gate valve	damaged, leakage and not working properly.	
18.3	Gate valve operating		

	systems		Need to replace
18.4	Gage valve control systems		
18.5	Main control valve to the Kugleschieberst		
18.6	Maintenance seal and control systems		
18.7	Maintenance seal		
18.8	Mounting valve for circulation line		
19	Turbine distributor systems with all accessories (wicket gate, servomotors, regulating rings, bearings, sealing elements, bottom rings, Kinematics systems, piping and valves, coupling systems and etc.)	Not in good condition	Need to replace
20	Turbine water piping and valves systems	Not in good condition	Need to replace
21	Turbine oil piping and valves systems	Not in good condition	Need to replace

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22	Turbine air piping and valves systems	Not in good condition	Need to replace
23	Penstock main inlet valve's bypass	The general penstock MIV's bypass valve for pressure difference between to side is working manually.	It is need to change the bypass valve to electric for automatic control of bypass.
24	Governing systems with all accessories	Not in good condition	Need to replace
25	Cooling water supply systems	Not in good condition	Need to replace
26	Turbine's air comprising systems with all accessories	Not in good condition	Need to replace
<b>Diversion dam and water tunnel</b>			
1	Diversion dam stop logs and trash racks	Not in good condition	Need to be rehabilitate, repair and overhauled



2	Water tunnel's gates and their accessories	<ul style="list-style-type: none"> <li>• Length of water tunnel from diversion dam to forebay = 3.6 KM with 2.8 M diameter.</li> <li>• Water tunnel from forebay to power house 335 M with 2.6 M diameter.</li> <li>• Water tunnel capacity = 22.5 M<sup>3</sup>/sec</li> </ul> <p>The water tunnel's gates and accessories should be control, inspect, verify and check for rehabilitation, repairing and overhauling.</p>	Need to rehabilitate, repair and overhauled
3	Water tunnel filtration systems	All filter should be verified, check and inspected.	Need to rehabilitate, repair and overhauled
Supplying of new equipment and spare parts are required			

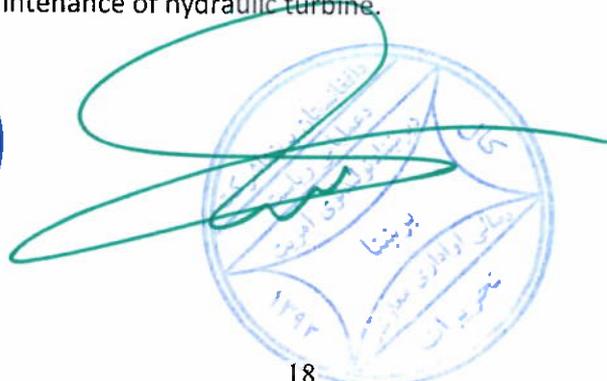
### 3.2.1 Standards and Regulations

Turbine shall meet provision made in the following standards (latest edition) unless otherwise mentioned.

1. IEC 41: 1991, Field acceptance tests to determine the hydraulic performance of hydraulic turbine, storage pumps and pump-turbine.
2. IEC 193: 1965, International code for model acceptance tests of hydraulic turbine.

Amendment No. 1 (1997).

3. IEC 193A: 1972, First supplement to IEC 193 (1965).
4. IEC 308: 1970, International code for commissioning, operation and maintenance of hydraulic turbine.



5. IEC 609: 1978, Cavitation pitting evaluation in hydraulic turbine, storage pumps and pump-turbine.
6. IEC 545: 1976, Guide for commissioning, operation and maintenance of hydraulic turbine.
7. IEC 60994: 1991, Guide for field measurement of vibrations and pulsations in hydraulic machines (turbine, storage pumps and pump turbine)
8. IEC 61362: -Guide to specification of hydro-turbine control systems.
9. ISO 3740: 1980, Acoustics- Determination of sound power levels of noise sources Guidelines for the use of basic standards and for the preparation of noise test codes.
10. IEC 61366 Hydraulic turbine of giving outputs higher than rated outputs to match 10% overload capability of the generator.
11. VDI 2056 and VDI 2059; Vibration level in rotating machines

The Supply of equipment and performance of the work must conform to the laws and regulations existing in Afghanistan, in addition to the particular prescriptions given in the present Technical Specifications.

Units of measurement shall be in the International System of Measurement (SI).

All materials and equipment to be incorporated in the Works and the fabrication of same, except as otherwise provided, shall conform to the international Standards as listed below:

AGMA	American Gear Manufacturers Association
AIEE	American Institute of Electrical Engineers
AISC	American Institute of Steel Construction
AISI	American Iron and Steel Institute
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineer
ASTM	American Society for Testing and Materials
AWS	American Welding Society
AWWA	American Water Works Association
CCITT	International Telephone and Telegraph Consultative Committee
DIN	Deutsche Industry Norman
EN	European Norms
ICEA	Insulated Cable Engineer Association
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronic Engineer
ISA	Instrument Society of America
ISO	International Organization for Standardization
ITU-T	International Telecommunication Union - Telecommunication Standardization



Bureau

NEMA	National Electrical Manufacturers Association
NEPA	National Fire Protection Association
SSPC	Steel Structure Painting Council
VDE	Verband Deutscher Elektrotechniker
VDI	Verein Deutscher Ingenieure

In case of discrepancies between these Specifications and international standards and codes, the international standards and codes shall prevail. Whenever these Specifications are more restrictive than national or international standards and codes, these Specifications being part of the Contract Documents shall prevail.

Utilization of IEC codes and ISO standards is compulsory; in case a contradiction is found between IEC and ISO, the IEC codes shall govern. Where no applicable international standards exist, national standards will be used.

If the Contractor, after the date of signature of the Contract, proposes other equivalent/superior Standards and Specification and Standards of equivalent material, the Contractor shall state the exact nature of the change, and shall submit complete Standards and Specification and information and data on the materials for the approval of the Employer at least 28 days prior to the date when the Contractor desires the Employer's approval.

The Contractor shall submit three copies to the Employer of the equivalent accepted standards in English or with English translation, showing the correspondence with the Standards specified.

Such submittal shall be timely and failure to do so, or purchase of any proposed equivalent materials prior to the approval of the Employer, will be at the Contractor's risk.

All documents such as drawings, descriptions, notices, letters, data, instructions, etc., shall be in English language.

### 3.2.2 Turbine Basic Data

Model: J.M. Voith (1965/66)

P = 22350 KW n

= 750 U/min Q

= 7.5 m<sup>3</sup>/sec

H = 335 m

For more details please see the drawing package.

### 3.2.3 General Information

The Vertical Shaft Francis turbine shall be directly coupled to synchronous generator of 26 MVA rating. The direction of rotation shall be clockwise when viewed from top. General arrangements of the power house and turbines have been tentatively outlined in contract drawings. Detailed information on water conductor system i.e. power channel, intake,

penstocks, tail race structure and other details of site are given in drawings and supplementary Information

### 3.2.4 Basic Provision

The turbine shall be giving a rated output of 26000 KVA (corresponding to 26000 KVA at generator terminals) at design head of 335 meter with guide vane opening of not more than 95%. The turbine shall have adequate capacity commensurate with the 10% continuous overload capacity of the generators at maximum head.

The turbine should be capable of operating between acceptable variation of rated head and acceptable variation of rated discharge as per latest IEC standard. The turbine shall comply in all respect of various standards with the requirement of the latest issue of IEC – 41. The specific speed of the turbine shall be selected as per the best modern practice and the turbine shall be of proven design. Similar machines designed on the basis of model offered against this tender should be under satisfactory operation at least on two different projects for at least last three years.

The turbine shall be so constructed as to allow all the removable parts to be dismantled conveniently. The design shall permit vertical movement of runner shaft by an amount sufficient for adjustment of bearings and for cleaning the joint at the coupling between the turbine and generator.

Contractor shall ensure the co-ordination between turbine & generator manufacturers (if both are separate) so that the generator to be coupled with the turbine is matched in respect of speed, runway speed, moment of inertia; overload capacities, coupling other relevant requirements.

### 3.2.5 Performance Guarantees

#### 3.2.5.1 Output and Efficiency Guarantees

Maximum Output and efficiency of the turbine at design head shall be stated in Guaranteed Technical Particulars of Turbine and will be guaranteed by Contractor. The turbine shall also be suitable for safe and efficient performance at part loads lesser than 60 (sixty) percent of rated output with minimum head conditions.

#### 3.2.5.2 Weighted Average Efficiency

The Bidder shall guarantee the weighted average efficiency of the turbine at rated net head using the weighted standard formula for the purpose of bid evaluation, calculation of amount of penalty and rejection limits of the equipment:

*The weighted average efficiency ( $\eta_t$ ) should be in high percentage (standard for Francis turbine)*

#### 3.2.5.3 Cavitation Guarantee

The Supplier shall guarantee the runner against excessive pitting caused by cavitation for 18 months from the date of commissioning or requires hours of operation, whichever is mention in IEC standard. In case of cavitation pitting exceeding the guarantee, the Contractor shall at his cost, take corrective measures such as repair as per original design, repair as per modifications or replacement etc., and turbine after modification etc., shall be subject to

A handwritten signature in blue ink is written over a circular official stamp. The stamp contains text in Urdu, including 'پراجیکٹ مینجمنٹ' (Project Management) and 'ہیڈ آف' (Head of). The signature is written in a cursive style.

fresh cavitation guarantee as for the original equipment. In determining whether or not excessive pitting has occurred, uniform metal removal by erosion, corrosion or by the presence of injurious elements in water, etc., shall be excluded.

#### 3.2.5.4 Vibrations and Noise Limit

Turbine design shall ensure smooth and quiet operation with low vibrations, pressure pulsation, power fluctuations and noise. The vibration amplitude at the shaft shall not exceed the values specified in ISO-7919 (part-1) and ISO-3945 or VDI 2056 and VDI2059 when measured with instruments with 1 Hz cut-off frequency. Maximum noise level resulting from any of the operating conditions shall not exceed 85 dB (A) at any place, 1.0 m away from any operating equipment in the machine hall.

#### 3.2.5.5 Runaway Speed

The maximum runaway speed shall be stated and guaranteed by the supplier. All rotating parts and bearings shall be capable of withstanding the forces and stresses occurring during runaway speed for acceptable standard time as per IEC or equivalent without any damage to any part. The guide bearing and guide cum thrust bearing shall be capable to withstand runaway speed for acceptable standard time as per IEC or equivalent without supply of cooling water and continuously with cooling water without abnormal increase of vibrations and temperature.

#### 3.2.5.6 Speed Rise, Pressure Rise and Inertia

The moment of inertia of the generating unit and closing time of wicket gate and runner blades shall be so selected that the maximum momentary speed rise of unit shall not exceed from standard allowable speed percentage of normal speed and pressure rise shall not exceed from allowable percentage of maximum head. The turbine manufacturer shall coordinate with the generator manufacturer for achieving the required flywheel effect.

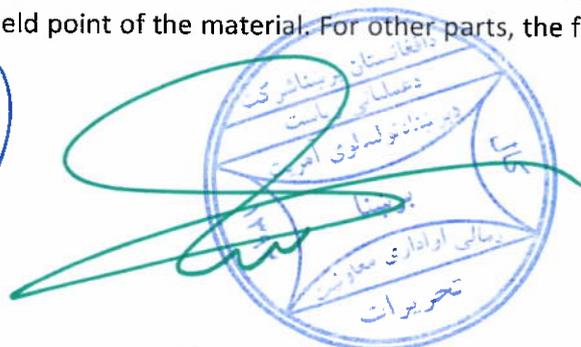
#### 3.2.6 Model Test

The Bidders shall offer the turbine with already tested model and proven performance of prototype machines at least at one project site for a period not less than three years.

The Bidder shall enclose copy of the relevant model test report with operating points of the turbine offered marked on the hill chart of the model to substantiate the output, efficiency and plant sigma figures offered and guaranteed by the Bidder. Bidder shall arrange certificate of trouble-free operation of the similar turbines from their owners and enclose the same in the technical Bid.

#### 3.2.7 Stresses and Factor of Safety

All parts of turbine shall be designed and constructed to safely withstand the maximum stresses during the normal running, runaway and short circuit conditions, out of phase synchronizing and brake application. The maximum unit stresses of the rotating parts shall not exceed two thirds of the yield point of the material. For other parts, the factor of safety



based on yield point shall not be less than three in normal conditions. Forevery-load and short circuit conditions, a factor of safety of 1.5 (one and a half) on yield point shall be permitted.

### **3.2.8 Deviations from Technical Specifications**

All deviation from General Technical Specifications and Particular Technical Specifications under this section should be clearly brought out at one place in the 'List of Deviations' from Technical Specifications. Any deviation not clearly mentioned in the List of Deviations, but described elsewhere in the equipment Description shall not be acceptable. After award of contract, the contractor has to fulfil all the requirements of technical specifications except the deviations clearly spelt out and accepted by Owner.

### **3.2.9 General Arrangement and Constructional Features of Turbine**

General Arrangement and Constructional Features of the turbine and associated equipment shall meet the requirements described below: All equipment shall be arranged so as to be easily accessible for inspection and maintenance without interfering the operation of other components.

### **3.2.10 Embedded Parts of Turbine**

The embedded parts of turbine such as draft tube knee lining and draft tube cone also spiral case where velocity of water is comparatively high as well as hydro mechanical parts like tailrace and stop logs, diversion dam stop logs, main inlet valve, gate valve control system, pressure systems and operating system shall be rehabilitated and overhauled as per latest technology and standard. The details of foundations and embedded pipelines at various levels for turbine, inlet valve, governing and auxiliary equipment will be supplied, rehabilitate and overhaul as per the relevant drawings.

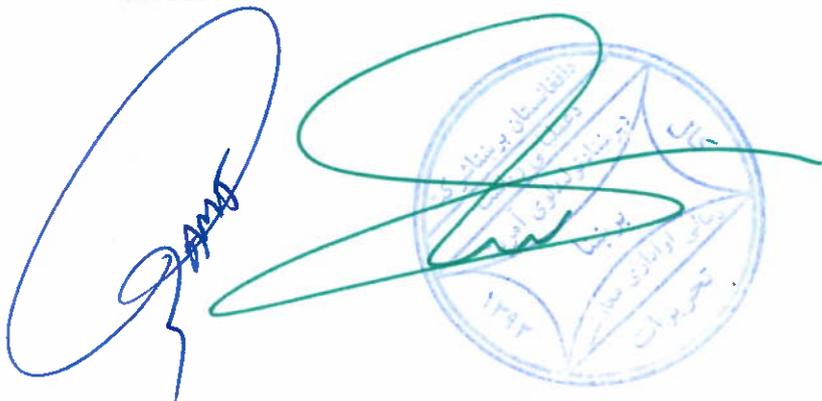
### **3.2.11 Foundation Rings**

Foundation ring of turbine is made by power plant maintenance team and they are not in standard situation. They need to be change and replace by new and standard foundation rings.

### **3.2.12 Runner with upper and lower labyrinths**

The turbine operating in the runoff river, MHPP turbines are facing sand erosion problem. The rate of erosion increases during the monsoon periods due to an increase in concentration of sand particles. Sand erosion rate is depended on particle velocity, concentration, operating condition, impingement angle and hardness of substrate as well as erodent itself. The components of Francis turbine namely guide vanes, faceplates, runner blades and seal rings are vulnerable parts to sand erosion. Thus, the turbine runner must withstand all mention problems and the turbine runner should be developed according to IEC requirements. Turbine runner shall be Francis type as per IEC and shall mainly consist of optimal number of blades with high efficiency.

### **3.2.13 Runner Blades**

The image shows a handwritten signature in blue ink on the left and an official circular stamp in blue ink on the right. The stamp contains text in Kannada and English, including 'ಕರ್ನಾಟಕ ಸರ್ಕಾರ' (Government of Karnataka) and 'ಜಲ ಸಂಪನ್ಮೂಲ ಇಲಾಖೆ' (Department of Water Resources). The signature and stamp are placed over the bottom of the text.

Runner blades shall be cast or construct as per IEC or equivalent, and reduced mass that enhances the hydrodynamic flow conditions and efficiency of the water turbine. The runner blades will be polished and ground smooth and will be free from roughness, blowholes, porosity, cracks and high spots etc.

### 3.2.14 Turbine's Distributer

The distributor of turbine such as wicket gate (guide vanes), lower rings, head cover (turbine cover), facing palates of bottom rings, guide rings, servomotor, kinematic systems, oil pipes and valves, water pipes and valves, air pipes and valves has water leakage, cavitation and metallic damage also eroded, rusted and oil leakage. These systems need to be replaced with new and modern systems as per international recognized standard.

It is required to replace the wicket gate (guide vanes) with all accessories and set them properly so that it can take have fully closed or opened positions and any position in between fully closed and fully open positions as per the requirement of the automatic governor system.

Turbine operating in sediment, excessive wear and damage often occurs on the guide vanes, facing plates, runner and labyrinth rings due to sand erosion. The requirement of dismantling the head cover to repair the facing plates and wearing ring is one of the major influencing parameters of turbine assembly design to increase down time during turbine maintenance. Thus, the standard assembly design of head cover is needed in hydropower station, including its effect on unit outage during overhauling of the machine. Design optimization of head cover has been carried out by considering the maintenance performance.

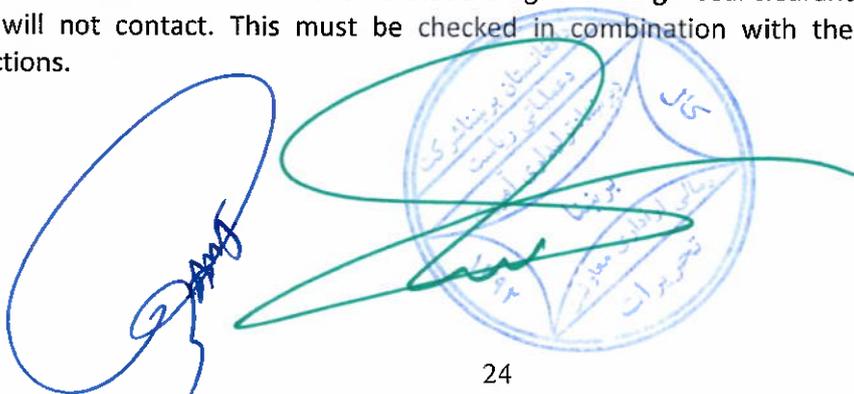
Servomotors, lower ring, facing plates of bottom rings, kinematic systems and all water, air and oil pipes and valves should be according to modern systems and technology.

### 3.2.15 Material

The material selected for upgrade constructions of hydraulic turbine runner has, over the years, become, almost exclusively, stainless steel. Martensitic grades of stainless steel (Chrome, Nickel percentage should be as per new and international standard) have been used to a large degree because these materials offer a combination of good weld ability, high strength, and cavitation resistance. Austenitic stainless steel offer excellent cavitation resistance and weld ability, but tend to have lower strength characteristics. Austenitic (chrome% to nickel% should be as per international standard) inherently have better corrosion characteristics than martensitic due to the higher chrome content. With any stainless, steps should be taken to avoid contamination during manufacturing and handling.

### 3.2.16 Deflection

The expansion of the runner crown and band (primarily, the band) for all normal operating conditions must be checked to ensure that the tight running – seal clearances at the wearing rings will not contact. This must be checked in combination with the shafting system deflections.

The image shows two handwritten signatures in blue ink. The signature on the left is a cursive name, possibly 'S. Ansari'. The signature on the right is more stylized and overlaps with a circular official stamp. The stamp contains text in Persian, including 'کابل' (Kabol) at the top, 'معاونت فنی و اقتصادی' (Technical and Economic Assistance) in the middle, and 'توسعه انرژی برق' (Electric Power Development) at the bottom. The stamp also features a central emblem.

### 3.2.17 Stress

The crown, band, and guide vanes, thicknesses should be compatible, particularly at the discharge edge junction of the blades, or vanes with the crown and band. This allows each component to carry its share of loads and moments without unnecessary constraint. Adequate stress transition must be provided between guide vanes discharge edges and crown and, to a lesser extent, the band.

### 3.2.18 Natural frequency:

The runner's natural frequency should be calculated to ensure that it is sufficiently separated from the normal operating frequencies of the unit to avoid resonance.

### 3.2.19 Turbine Shaft & Coupling

The turbine main and middle shafts shall be designed to operate safely in combination with the generator rotor at any speed up to the maximum runaway speed without detrimental vibration or objectionable distortion. It shall operate at the rated speed and maximum specified output without exceeding the maximum allowable stresses. The couplings for connecting to turbine runner and generator rotor shall be friction type with pre-stressed coupling bolts. The tightening torque for coupling bolts will clearly be mentioned on drawing. If necessary, torque transmitting pins will be provided on coupling flanges. Proper size rubber cords shall be used between coupling joints. Torque tightening wrench will be included in scope of supply under special tools. The main and middle shafts and coupling bolts of all the units shall be made interchangeable.

The turbine main and middle shafts should be as per International Standard. It will have integrally forged coupling flanges for coupling to generator shaft at upper end and turbine runner at lower flange. The shafts are provided with a bearing belt. Necessary tackles and devices shall be included and supplied for lowering the shaft with runner in turbine pit and coupling the same with generator shaft.

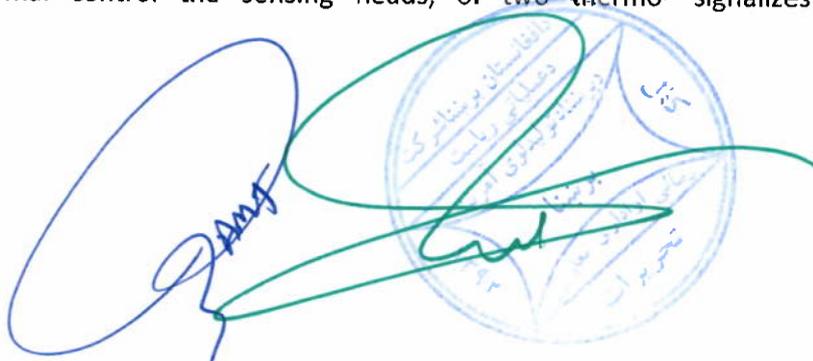
### 3.2.20 Bearing of Turbine

Turbine bearings is recommended to offers the lowest coefficient of friction, superior adhesive wear performance and good resistance to wear resulting from third particle abrasion. The bearing should be specially formulated to provide optimal wear resistance in abrasive-laden water conditions.

Self-lubricating turbine bearing shall preferably be segment type and adequate number of Babbitt lined segments shall be used along the outer circumference of the bearing belt of the shaft. Arrangement shall be provided to adjust the bearing gaps and lock the pads in position. Alternatively, shell type bearing can also be offered.

Contractor should find the optimality between Babbitt and fluoroelastomer performance for turbine bearing, if fluoroelastomer performance was better than Babbitt thus the existence Babbitt should be changed by fluoroelastomer as per international standard.

Level relay with alarm shall be provided for indicating low oil level in the bearing body. For thermal control the sensing heads, of two thermo- signalizes and two resistance



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thermometers shall be provided in the bearing segments/shell. An Electro contact flow relay shall be provided for signaling the stoppage of flow of cooling water supply.

**Note:**

The type of bearing that offers adjustability, good combined (oil and structural) stiffness, and the closest load support to the runner is the adjustable shoe or segment bearing. The resulting close proximity of the bearing to the runner, and, therefore, the shaft seal, limits space and precludes the use of a large oil basin necessary for a self-pumping bearing. Therefore, the benefits of this bearing arrangement are fully realized when the lubricating oil is pumped from an external sump that includes cooling coils (or heat exchangers). Controls, redundant pumps and motors.

**3.2.21 Turbine Shaft Gland**

The turbine shaft gland shall effectively prevent leakage of water along the shaft under all operating and standstill condition and prevent entry of air. Shaft gland shall be of stuffing box (carbon ring) type with self-lubricated packing and lantern ring. Any other suitable type of shaft gland will also be considered. Arrangement of providing clean cooling water supply to the gland at pressure sufficient to stop dirty water coming up shall be made by the Contractor. A pressure gauge and an Electro-contact flow relay shall be provided for measuring the pressure in the turbine seal and signaling the stoppage of flow of cooling water supply.

**Note:**

Two versions of the basic "axial" face seal concept have been used: hydrostatic, which requires clean water injection into the sealing interface, and hydrodynamic, which generates its own interface liquid film by using the fluid being sealed.

The use of hydrostatic seals is especially advantageous when the following special operation requirements exist:

- Lowest possible face wear rate;
- Contaminated operating water, particularly when the contaminants are abrasive solids;
- Synchronous condenser operation (with runner operating in air)

The packing-box type of main shaft-seal is the simplest configuration of the mentioned shaft seals. The sealing element is generally a series of square woven packing compressed by a packing gland to provide sufficient packing pressure on the main shaft to provide controlled leakage through the packing box. It should be pointed out that packing box seals require a small amount of leakage to cool the seal properly. For shaft seals where the seal remains submerged even at minimum tailrace water elevation, a separate maintenance seal is normally specified. This maintenance seal, when actuated, will allow exchanging the main sealing elements of the shaft seal without dewatering the draft tube.

The image shows two handwritten signatures, one in blue ink and one in green ink, overlapping a circular official stamp. The stamp is blue and contains Arabic text, including the name 'مؤسسة كهرباء لبنان' (Lebanese Electricity Corporation) and the year '١٩٨٣' (1983). The signatures are written over the stamp and extend to the left.

### 3.2.22 Mounting of Shear Pin Contact

The limit switches shall be provided for the shear pins/breaking links to give the alarm signal when any of the shear pins / breaking links gets broken due to jamming of guide vanes. The cables used for interconnecting the limit switches shall be weather proof type and withstand the surrounding moist atmosphere. The limit switches shall be oil/water tight and special glands be used to prevent entry of water in the limit switches through the cables.

### 3.2.23 Centralized Grease Lubrication System

The centralized grease lubrication system shall be of adequate capacity to pressurize the turbine grease lubrication points periodically by time as per requirements. The equipment comprises of an electric motor driven grease pump, starter, grease reservoir, pressure regulator, solenoid valve, set of grease dozers and pipes etc. The control panel with control indicators, manually starting push buttons, fault indicators etc. shall be supplied. The control panel shall be of wall mounted type. One hand operated transfer pump shall be supplied for transferring grease from commercial standard grease drums to reservoir of automatic grease lubrication system. One number manually operated pump for greasing the points when the automatic system is not in operation shall be supplied.

### 3.2.24 Turbine Instrumentation, Control, Safety Devices and Unit Control Board

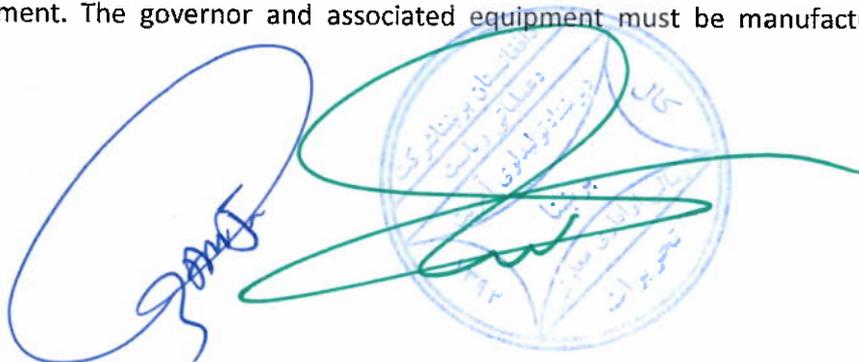
Each turbine shall be provided with a complete set of instruments, gauges, controls and safety devices on unit control board provided for monitoring the condition of the unit during normal running and emergencies. These shall permit the unit to be started and brought up to speed no load position at the governor location and control during normal running. The instruments and gauges for the turbine include, inter alia, pressure gauges, level indicator, indicating lamps for status indication etc. These shall be placed near the locations of apparatus or in the Unit Control Board (UCB) or both.

The safety devices shall comprise equipment and devices for sensing abnormal operating conditions, for giving visual and audible annunciation and shut down the unit, if required. Quantities and location are to suit the requirements for safe and satisfactory operation of the generating unit 1 and the auxiliary systems.

The turbine instrumentation, control, safety device should be digital, computerized and remote control systems.

### 3.3 Governing System and Accessories

The governor and associated oil pressure system shall be of modular type of proven design suitable for control and operation of the Francis turbine unit. It must be manufactured by a reputed international company specialized in the production and distribution of governor equipment. The governor and associated equipment must be manufactured and tested

The image shows two handwritten signatures and two official stamps. On the left, there is a blue ink signature. To its right is a circular blue ink stamp with Persian text. Further right is a green ink signature, and to its right is another circular green ink stamp with Persian text. The stamps appear to be official seals of an organization.

according to IEC 60308“International Code for Testing of Speed Governing System for Hydraulic Turbine”. The Bidder shall supply a type and routine test report of the governor confirming to the similar type being offered in this bid.

### **3.3.1 Rating, Performance and Basic Provisions of Governor**

The governor shall be Digital electronic type with electronic speed sensing, electronic hydraulic transducer, and oil-pressure actuator. It shall have adequate capacity to operate the wicket gate servomotor through a complete opening or closing stroke in desired time under maximum operating head and with minimum permissible oil pressure in oil pressure accumulator.

The governor shall meet the requirements of IEEE –125 “Recommended Specification for Speed Governors of Hydraulic Turbines”.

### **3.3.2 Stability (Current Practice)**

The governor operation shall be deemed stable: If peak to peak magnitude of the sustained load oscillation caused by the governor, with 4% or more speed droop setting, does not exceed  $\pm 0.15\%$  of the rated capacity -the generator being connected to the grid with sustained load demand. The governor shall control, with stability, the turbine at any speed between 85 and 105% of rated speed when operating isolated from the system and while connected to the system at any load between zero and the load corresponding to maximum opening of the guide vanes.

With the turbine running at its rated speed, the total amplitude of speed variations not resulting in any measurable difference in the guide apparatus servomotor position shall not exceed 0.02% of the rated speed at any gate opening.

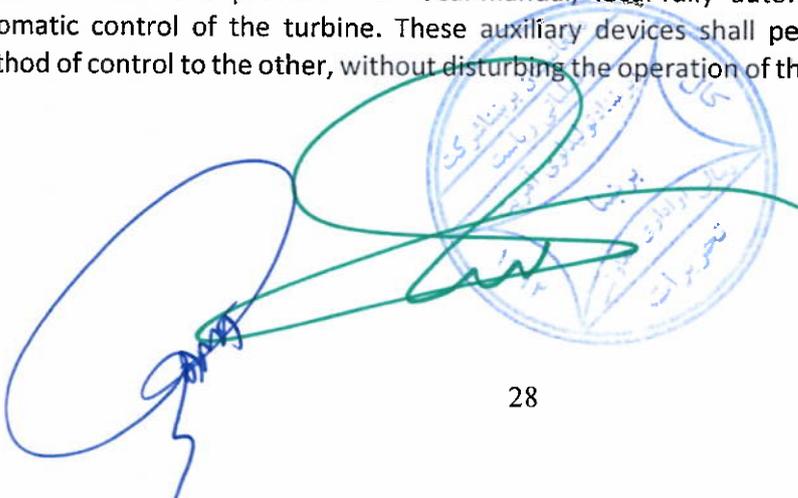
### **3.3.3 Dead Band**

The dead band adjustment range shall be 0 to  $\pm 3$ Hz. The governor dead time shall not exceed 0.2 seconds with a sudden load change of 10% or more of the capacity of the turbine.

**The adjustment of permanent speed droop shall have a range from 0 to 10%.**

The governor adjustments shall enable synchronizing over the range of 85 to 105% of rated speed and shall be adaptable for automatic synchronizing and automatic load or frequency control.

Governor shall have provision for local-manual, local-fully automatic and remote fully automatic control of the turbine. These auxiliary devices shall permit transfer from one method of control to the other, without disturbing the operation of the turbine. Transfer from



The image shows a handwritten signature in blue ink over a circular official stamp. The stamp contains Arabic text, including "السلطة الوطنية للمياه والكهرباء" (National Authority for Water and Electricity) and "العمارة" (Architecture). The signature is written in a cursive style.

local to remote control will be initiated by a two-way position selector switch located in UCB (Unit Control Board).

The electronic regulation panel shall be micro-processor based digital system of proven design. Governor shall use PID (Proportional Integral Derivative) loop control in which three derivatives of speed are used for speed stabilization.

Control modules of governor regulator shall be suitable for auxiliary supply voltages:

Starting and stopping of the generating unit shall be possible locally from the governor panel and also remotely from Microprocessor based DACS and auto start/stop control system (Unit control boards).

Governing shall be fail-safe on the failure of the speed sensing element, loss of oil pressure or defect in the actuating system so that under any of these conditions, the machine shall be automatically shut-down, with alarm and indication.

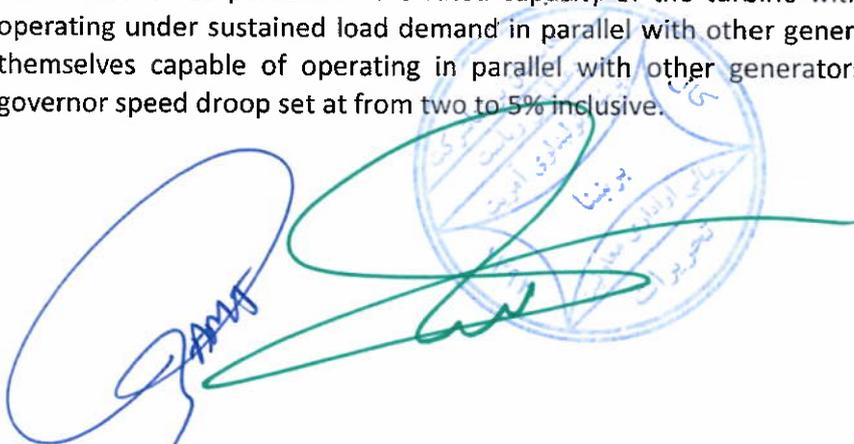
Provision shall be made in each governor regulator to control wicket gate opening based on water level in power channel so as to utilize available water for power generation and avoid flowing through bypass gates. Sufficient flexibility will be provided in control philosophy to choose control of any of the unit using load frequency control, gate limit control, manual control and control as per water level in power channel.

Hand control device for stroking of governor shall be provided Partial Shutdown / Controlled Action Shutdown device shall be used for automatically shutting down the turbine to the speed-no-load position by the operation of certain protective devices.

### 3.3.4 Performance Requirements as follows were generally specified earlier

**3.3.4.1 Stability:** The governor system shall be capable of controlling with stability the speed of the turbine when operated at rated speed and no load or when operated at rated speed with isolated load at all power outputs to and including maximum output of the turbine. The governor system shall also be capable of controlling with stability the power output of the turbine at all power outputs between zero and maximum power output of the turbine at all power outputs between zero and maximum power output inclusive when the generator is operating in parallel with other generators in a plant or in a transmission system. The governor system should be deemed stable, if the hydraulic system of turbine and water conduit is inherently stable, when:

- The magnitude of the sustained speed oscillation caused by the governor does not exceed 0.3% of rated speed with the generator operating at rated speed and no load or operating at rated speed and isolated sustained load and with the governor speed droop set at from two to five percent inclusive.
- the magnitude of the sustained power output oscillation caused by the governor does not exceed three percent of the rated capacity of the turbine with the generator operating under sustained load demand in parallel with other generators which are themselves capable of operating in parallel with other generators and with the governor speed droop set at from two to 5% inclusive.

The image shows two handwritten signatures in blue ink. One signature is on the left, and another is on the right, overlapping a circular official stamp. The stamp contains text in Arabic, including 'مديرية الموارد المائية' (Directorate of Water Resources) and 'بغداد' (Baghdad). The signatures are written in a cursive style.

**3.3.4.2 Dead Time:** The elapsed time from the initial speed change the turbine servomotor for a sudden load change of more than 10% of the full load rating of the turbine shall be not more than 0.25 second as demonstrated during field tests.

**3.3.4.3 Dead Band:** The total magnitude of the sustained speed change within which there is no resulting measurable change in the position of the turbine gate servomotors at rated speed of the turbine shall not exceed 0.02% of the rated speed of the turbine at any gate opening as demonstrated by shop tests. For purpose of determining compliance with guaranteed characteristics, the minimum speed change in % of turbine speed to which the governor will respond is defined as one-half the measured dead band.

**3.3.4.4 Speed response Elements:** The speed of the speed responsive element shall vary directly with the speed of the main shaft of the turbine for all rates of acceleration and deceleration. The governor drive shall not be affected by variations in the voltage or current of the main generator or exciter or of the power system to which the main generator is connected.

### 3.3.5 Working Principle

Working principle of Governor Controller will be as follows:

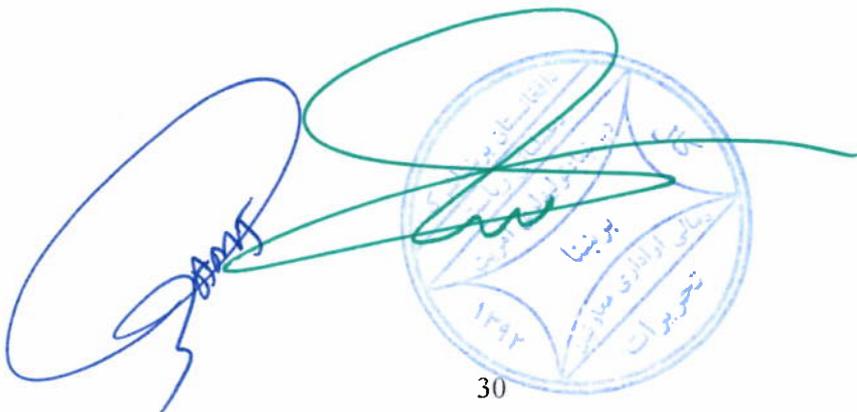
The speed signal will be derived from Speed Signal Generator (SSG). This signal will be converted to a DC signal by a pulse converter and a frequency to voltage converter. Feedback signal corresponding to gate position will be obtained from a variable resistor or a LVDT. The subsequent stages of control and regulation will be carried out in the microprocessor hardware. The required transfer function for the controller will be realized in software by using suitable function block language. The reference values (Speed setting, Gate setting, Gate limiter position etc.) and parameter values of PID controller, temporary and permanent droop functions will be set in the processor.

The reference values to be varied using raise/lower switches in the panel and parameters to be set during commissioning using programming tool. The output of the regulation function block will be fed to an analog output module. This signal will be further amplified by a booster amplifier and fed to electrohydraulic transducer in actuator cubicle.

### 3.3.6 Constructional Features

The governor electronic cubicle should have the following features:

- Modular, bus-based architecture which will allow flexibility in hardware configuration.
- Inter module communication through serial bus.



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- Module level self-diagnostics to be ensured. Each module shall contain circuits for monitoring its most important functions. If a fault occurs, the type and possible location to be indicated by light emitting diodes and output signals
- Non-volatile RAM (read only memory) to be made available on the processor module for retaining important parameter values even when power failure occurs.
- Power supply requirement: Station battery 220/240 /24 V DC.

**3.3.6.1 Software:** A complete set of programmer and data base files and software configuration and programming tools shall be provided for all digital devices installed in the system as per IEEE 125. Interface to other plant systems shall be provided as follows: Interface to unit controllers, plant controller central control room, plant monitoring system and remote terminal unit for offsite control as required.

- PID/temporary droop control scheme for regulation.
- Start up and Shutdown logic.
- Speed relays.
- Electronic limit.
- Function block programming language to be used same as in Unit Control panels
- The digital modules used in the controller belong to the same family hardware which are also being used in unit Control Panels.

The cubicle shall be a steel cabinet with doors for convenient adjustment, test and maintenance. Micro terminal for indications and control shall be mounted on the front rack with transparent cover. The cubicle shall be mounted at a suitable location along with unit control board panels.

All electrical wiring shall be neatly concealed inside the cubicle and terminated in readily accessible terminals. Cable entry shall be from below the cubicle.

All settings like speed droop, temporary droop on line/ off line, temporary droop time constant on line/ off line, dead band, permanent speed droop and sensitivity etc shall be achieved through digital type micro terminal. It should be possible to change the once adjusted values through password only.

Governor shall accept digital set commands from unit control panels for various controls i.e., speed / gate setting, limit setting, start, stop, main circuit breaker position, Shutdown, and other signals necessary for proper operation and as per logic control scheme approved by purchaser.

Following analogue/digital output signals shall be provided as input for unit control panels:

- Speed, Wicket gate position and gate mechanical limit position, Wicket gate electrical limit,
- Actuator balance current, Speed setting, Gate setting, Speed relay signals,

- Position of various limit switches, position of various solenoids and any other signal considered necessary for ensuring proper control

Command signals at the following speeds shall be available at regulator output terminals:

- At speeds above 120 % of rated speed to cause unit shut down through the shutdown solenoid via protection circuits
- At 90 % of the rated speed for initiating excitation and synchronizing functions.
- At 80 % of the rated speed for changing over the governor to auto speed regulation.
- At 25 % of the rated speed activate the generator brake application.
- At zero speed to indicating unit standstill.
- At 150 % speed to announce emergency condition and drop intake gates.

### 3.3.7 Electro-Hydraulic Actuator

The electro-mechanical transducers, pilot valves, main distributing valve for wicket gates and runner blades control, auto clean strainers for transducers / pilot valves, shutdown solenoid, terminal blocks and other accessories necessary for the hydraulic actuator shall be housed in a suitable cabinet. Following indicators shall be mounted on the front panel of the actuator:

- Wicket gate position and gate mechanical limit position indicator
- Speed Indicator (with marking as 0 to 200 %)
- Actuator balance current indication
- Speed setting indicator (with marking as 45 Hz to 55 Hz)
- Gate setting indicator (with marking 0 to 100 %)
- Runner Blade angle indicator (with marking – min. to max blade angle)
- Pressure gauge for oil pressure in transducer

Following controls shall be provided on the actuator cubicle:

Gate limit control device which can be operated manually at the actuator and electrically from the unit control board (suited to 220 volts DC). Manual gate control should be possible by this device when control changed over to 'Manual' Push button for Auto/ Manual Changeover for Gate Control. Device for Manual Control of Runner Blades during maintenance Emergency shutdown device which can be operated manually at the actuator, electrically by remote control or by emergency shutdown signal from Unit Control Panels. Auto clean double element filter set shall be provided in governor actuator to ensure that impurities of 10 microns or above are avoided. The changeover to standby filter and cleaning of clogged filter must be possible while unit is under operation.

The control mechanism shall be equipped with means of independent adjustment of the opening and closing times of the guide vanes and gate valve. The adjustments shall be secured and will not be liable to change at its own under any circumstance. The time for the gate closure under full load throws off shall be adjustable to limit the speed rise and pressure rise

within guaranteed values. All bearings in the governor actuator cubicle shall be grease packed or self-lubricated.

### 3.3.7.1 Gate Position Switches

A bank of switches / master switch assembly will be provided in actuator cubicle or on the restoring system. Its switches shall be adjustable independently corresponding to different positions of wicket gates as desired for fulfilling the requirement of control sequence. At least two switches will be provided for gate full closed position and two switches for slightly higher position than no load gate position.

### 3.3.8 Speed Signal Generator (SSG)

A toothed wheel type speed signal generator shall feed speed signal to the governor electronic cubicle for regulation and speed relays. The toothed wheel shall be mounted on the turbine shaft and two magnetic pick-ups shall be mounted near the toothed wheel. One of the two pickups will work as redundant. The square wave output of the magnetic pick-up shall be fed to the frequency-to voltage converter module in the governor electronic cubicle. The output of this converter shall be fed to the governor analogue input signal module. The capacity and characteristics of the SSG shall fully match with the requirement of speed responsive elements and governor regulation and control system. It shall be designed to withstand satisfactorily the maximum runaway speed of the turbine. The digital governor shall have the provision of speed sensing through a potential transformer. The PT shall be included in the scope and provision of its mounting in the LAVT cubicle. The VA burden and classification of PT shall be as per IEEE.125.

### 3.3.9 over Speed Device

A centrifugal type over speed protection device with provisions for electrical and mechanical tripping shall be mounted on the turbine shaft above the guide bearing. The tripping points shall be adjustable independently for speed higher than the maximum speed the turbine can develop with loss of full load. The mechanical tripping device shall directly actuate the governor actuator shut-down valve through a hydraulic connection. The electrical tripping contact shall be wired to the turbine terminal cubicle.

The rotating parts of the over speed protection shall be protected by a guard.

### 3.3.10 Restoring Mechanism

Restoring mechanism – solid rod & levers, wire rope with pulleys or fully electronic, will be provided to feed position of wicket gate to governor for stabilizing and indication. Design of restoring mechanism should ensure minimum backlash to achieve overall sensitivity of the governor. Mechanism shall be provided to monitor the health of restoring mechanism so as to give emergency shutdown signal in case of its failure.

33



### 3.3.11 Oil Pressure System

The turbine will be provided one independent oil pressure unit to supply oil under desired pressure to guide apparatus servomotor through governor hydraulic actuator. Oil pressure system shall consist of oil pumping unit and an air-oil pressure accumulator. The operating oil pressure shall be not less than 64 kg/cm<sup>2</sup>. The bidder may offer higher operating pressure if the runner operating mechanism permits so. While selecting the operating oil pressure, care should be taken that servomotor should be capable of closing the wicket gates under all operating conditions at the emergency low pressure.

*In SHP Oil Pressure system of higher rated pressure with Nitrogen Cylinders can be offered as ALTERNATIVE offer with explanation of advantage and cost benefits.*

#### 3.3.11.1 Oil Pumping Unit

Oil pumping unit shall consist of one sump tank with two numbers oil screw pumps driven by a 3 phase 415 VAC electric motors, check valves, idler and relief valves, oil level indicator and transmitter, oil filters at the suction of pumps and oil temperature detector. The sump tank shall have adequate capacity to drain the entire governor oil system including servomotors. It shall be provided with a manhole and oil centrifuging and drain connections. The oil pump shall be screw type and have a capacity sufficient to operate the complete governor hydraulic system as per need, when operating under the recommended pressure. The main duty pumps shall be operating continuously even when the required pressure in oil pressure accumulator has been built up.

The electric motors shall be direct connected 3 phase AC motor, 415 volts + 10%, 50Hz completely enclosed frame, squirrel cage rotor type with class F insulation.

The motor starter panel housing contactors switch fuse units and meters etc. shall be mounted on the wall near the sump and wired complete with leads labelled. The connections to each motor shall be arranged so that either pump may be removed for repair or replacement without interfering with the continuous operation of the other. A complete pump logic control system shall be provided in the main PLC system of turbine control. It will permit the selection of either pump, as the main unit with the other pump acting as a standby, which will cut in automatically to supply the oil and close a set of alarm contacts. Suitable number of adjustable differential pressure switches will be used to obtain the desired logic.

#### 3.3.11.2 Oil Pressure Accumulator

The capacity of the pressure accumulator shall be sufficient to operate the servomotors of the turbine, with minimum pressure of normal operating range and under other normal



operating conditions, through three complete servomotor strokes. Design calculation of capacity of oil pressure system shall be furnished.

The pressure tank shall be constructed in accordance with part UW of the ASME Code for Unfired Pressure Vessels, Section VIII, for the maximum working pressure of the governing system.

Following safety / control features shall be provided on the accumulator:

- Air pressure relief device, mounted on or near the top of the tank.
- Two low oil level devices with independently adjustable closing contacts
  - ✓ One low oil level device shall be set to operate an alarm when there is sufficient oil under pressure to provide only two full strokes of all servomotors.
  - ✓ The other low-level device shall be set to shut down the unit when there is sufficient oil under pressure for approximately 1-½ strokes.
- Two oil level devices with independent adjustable contacts for control of high-pressure air replenishment.
- Sight oil level gauge with guard, shut off valves and automatic shutoff device.
- Connection for compressed air line with shutoff valve and check valve.
- Air blows off valve, pressure gauge, manhole, drain connection, lifting lugs, anchor bolts, and all necessary equipment for a complete assembly.

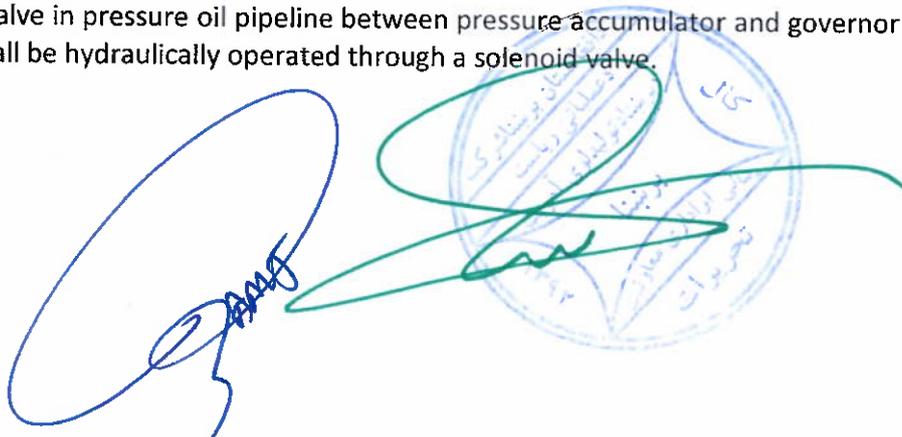
### 3.3.11.3 Oil Leakage Unit

One oil leakage unit will be provided to collect leakage oil from servomotor, oil distributing head and other governing elements. Provision shall be made to drain oil pipelines and servomotor through oil leakage unit and pump it to oil handling system or OPU sump. Oil leakage unit should consist of one oil tank of at least 100 liters, one pump motor set with set of valves, oil level relay and sight gage glass.

### 3.3.11.4 Oil Pipe Lines

Oil pipe lines of adequate size along with necessary valves, connecting flanges, fittings and fasteners shall be supplied for interconnection between different hydraulic elements. Sufficient joints will be foreseen in pipelines for their easy dismantling and cleaning. Pipelines shall be fabricated at site to suit the civil structure of the power house and provide neat layout. All weld joints in pipelines shall be done by Tag welding and inside surfaces of pipes will be cleaned by metal wire brush and acid pickling and flushed to metallic shine. All pipes above 15 mm internal diameter shall be stainless steel seamless pipes and up to 15mm size, these will be stainless steel pipes. Pipes shall be rigidly clamped on walls, floors or trenches with suitable clamps to avoid their vibrations. Covers for trenches shall be included in the pipeline scope of work.

Isolating valve in pressure oil pipeline between pressure accumulator and governor actuator cubicle shall be hydraulically operated through a solenoid valve.

The image shows two handwritten signatures. The one on the left is in blue ink, and the one on the right is in green ink. To the right of the signatures is a circular official stamp in blue ink. The stamp contains text in Urdu, including 'کمال' (Kamal) at the top, 'پراجیکٹ مینجر' (Project Manager) in the center, and 'پاور ہاؤس' (Power House) at the bottom. The stamp also features a central emblem.

### 3.4. Cooling Water Supply System

The cooling water for unit # 1 turbine and generator shall be taken from the tailrace and supplied to each cooling system through a strainer for debris removal before being used in the cooling system and discharged to tailrace (that the water from tailrace is always contaminated then should be filtered by filter before supplied to the cooling systems). An alternative option of supplying the cooling water directly from the penstock shall also be implemented. The cooling system to be supplied by this system shall comprise:

1. Generator air coolers
2. Generator thrust and guide bearing oil reservoir cooler
3. Turbine guide bearing oil reservoir cooler
4. Turbine shaft sealing
5. Governor oil sump tank cooler, if required
6. Forced air admission compressor cooler, if required
7. Any other items of plant requiring a supply of cooling water while the unit is operating the cooling water supply system shall be designed to furnish the maximum quantity of cooling water at normal pressure required for the coolers.

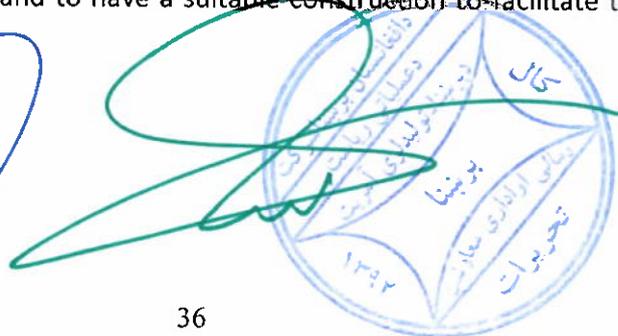
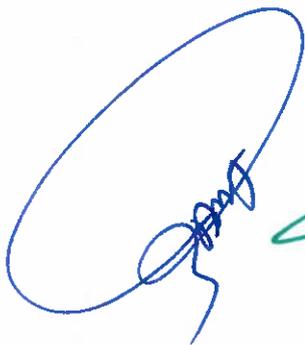
Alternate arrangement of cooling water system shall be included in the contract.

#### 3.4.1 Cooling Water Pump

Two AC motor-driven cooling water supply pumps shall be provided for unit # 1 to supply the cooling water. Each pump shall have an ample capacity to continuously use for all coolers at suitable working head and self-priming type. The pump shall be equipped with necessary pipes, valves and strainers. The pump shall be designed as to easy maintain in turbine room. The automatic control of the two pumps for unit # 1 shall be such that either pump may be used for normal operation, with the other pump serving as a standby. The standby pump shall be arranged to start automatically when the normal use pump will stop by accident. A changeover switch shall be provided on the motor control center to enable either pump to be selected as the standby unit. A "Remote-Local" changeover switch shall be provided. When the normal operating pump stops by failure of electric power source, the pump shall start again automatically upon restoration of the power source.

#### 3.4.2 Strainer

There shall be two strainers in each circuit. First in line shall be a hand-operated type rotary strainer. Each strainer shall be of hand-operated rotary type and have an ample capacity for the turbine generator demand. The strainer element shall be of stainless steel or bronze and shall be readily cleaned. The strainer shall be designed for safe operation at a maximum output pressure of the pump and to have a suitable construction to facilitate the cleaning



under running of the turbine generator. All connections and valves necessary for the normal operation, servicing and back flushing of the strainer elements shall be provide.

The cleaning of the strainer element shall be assisted by rotating the strainer element past a backwashing element or by means of a rotating scraper. All rotating elements shall be supported in bronze bushing and shall have stainless steel sleeves or shafts where in contact with the bushing. Suitable seals shall be provided at the shaft of the rotating element. The water strainers shall be of duplex type, rotary and electrically controlled.

-It shall be mechanically enclosed rotary drum pressure type.

-Body shall be welded steel or cast iron to ASTM 278 class 40 constructions with 316 stainless steel liner.

-It shall have removable cover with drive unit and water tight reduction gear.

-It shall have self-cleaning drum with stainless steel removable filter elements. Backwashing shall be based on pressure differential across the straining element.

-Each filter of the component shall be supplied with its electrical control box fully equipped for automatic operation.

### 3.4.3 Piping and Valve

The water piping shall be complete with all necessary pipes supports. Couplings flanges expansion joints fasteners and valves. All valves shall be provided with hand wheels of ample size and extended spindles and/or gearing where necessary for convenience and ease of operation. The valves shall close with a clockwise rotation of the hand wheel, which shall be marked to show the direction of closing

### 3.5. Lubrication Oil Sump Tank

A lubricating oil sump tank shall be provided for reservation of the turbine guide bearing and the generator thrust and guide bearings oil for maintenance. The lubrication oil sump tank shall be provided with one (1) gear type oil pump sets, valves and pipes to drain and supply to the all bearing oil tank for unit # 1. Clean oil shall be pumped from the sump tank to the unit # 1, and drainage oil for maintenance purpose shall be conveyed by gravity from the unit # 1 to the sump tank. A detailed description on the requirements of lubricating oil system will be appropriate.

### 3.6. Water Discharge System

1. The water from coolers shall be discharged to the tailrace. A common discharge pipeline may be used for unit # 1.
2. An isolating valve shall be provided on each discharge line inside the powerhouse, to allow servicing the piping system.
3. The water from all other items and strainer back-flushing facilities shall be discharged to the drainage sump pit of the powerhouse. The water in the draft tube shall be discharged to the drainage sump pit.

The image shows two handwritten signatures in blue ink. The signature on the left is more stylized and includes the letters 'AM'. The signature on the right is more fluid and cursive. To the right of the signatures is a circular official stamp in blue ink, which contains Arabic text and a central emblem, likely representing an official organization or authority.

4. The drainpipe for draft tube shall be provided with two (2) hand-operated valves at convenient location to operate. The water in the spiral case shall be discharged through the draft tube to the drainage sump pit when the runners or the inside of turbine is to be inspected.
5. The water in the penstock shall be discharged to the tailrace by the drainpipe. Necessary valves and pipe shall be provided.
6. The exposed and embedded piping shall be steel piping complying with General Technical Specification. Due allowance shall be made, in selecting the material and designing the pipe, for the temperature of the discharge water from the heat exchanger

The piping material selected shall be preferably is the same as that used in the water supply system. The system shall be designed so that the exposed piping can be readily dismantled for cleaning.

The Engineer shall approve the material and design criteria.

### 3.7 Accessories

#### 3.7.1 Ancillary Electrical Equipment

All electrical equipment, except electronic equipment shall be suitable for the power supplies specified.

The Contractor shall supply all motors, solenoids, limit switches, and float switches, relays and other electrical items, which are an integral part of or are directly mounted on the equipment supplied under this Contract.

All motors shall be continuously rated and shall be squirrel cage induction drip proof type with class-B or E insulation, ball or roller bearings, suitable for full voltage starting. The windings shall have moisture and oil resistant impregnation. Wherever possible, solenoids shall be so arranged that they do not remain continuously energized while the unit is running or standing. As far as possible, electrical components, starters, relays, switches, etc.

Of similar rating shall be interchangeable with those supplied under separate section.

#### 3.7.2 Oil and Grease

The bearing and governor system shall be filled with lubricating oil and pressure oil and extra 50% of it shall be supplied in sealed non-returnable drums. Sufficient grease and other lubricating oil shall also be supplied for five years of smooth operation. The tenders shall supply detail specification of lubricating oil, pressure oil, grease and other lubricating oil.

#### 3.7.3 Accessories

The Contractor shall supply the following:

1. All necessary soleplate, foundation, anchor bolts, channel steel, angle steel and shim plates for the turbine and associated equipment.

2. All necessary checkered plate for completing the floor around all valve spindle and other parts supplied under this section, which pass through the floor and are not concreted in.
3. All platforms, ladders, guards and handrails necessary for obtaining easy and safe access to the equipment supplied under this section.
4. A nameplate for each separate item of plant. Showing the maker's name serial number year of manufacture rating capacity and other main characteristics.
5. All necessary lifting lugs eyebolts and other items required facilitating handling and serving the installation.
6. All necessary turnbuckles pipe jacks, liners etc. required for the installation of the distributor and discharge pit.
7. Sealing materials
8. Electrical equipment
9. Electrical materials

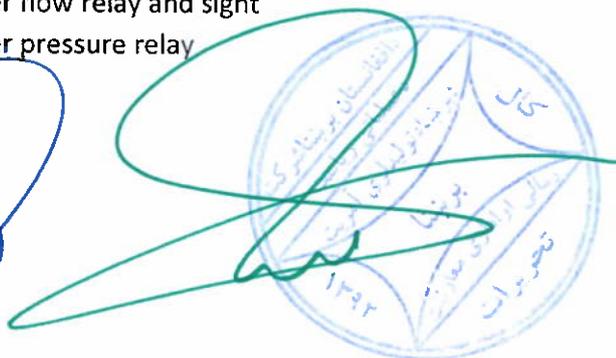
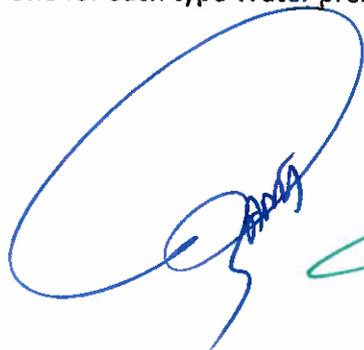
### 3.8. Spare Parts

The spare parts should be sufficient for five years of trouble- free operation of the unit # 1. Besides, the option of having a complete set of turbine parts, so that the stoppage time of the unit # 1 could be substantially reduced during the overhauling period of the unit # 1, should also be considered.

The following spare parts shall be furnished and quoted separately from the main equipment for one unit.

#### 3.8.1 Turbine Parts

- (1) A quantity equivalent to 10% of all fasteners, nuts and washers,
- (2) One complete set of turbine's bearings.
- (3) One sets of dial thermometer for turbine guide bearing.
- (4) One complete set of stainless-steel shaft sleeve for the turbine shaft
- (5) One complete sets of shear pins for wicket gate for turbine unit
- (6) One complete sets of metal rings or carbon rings for the turbine shaft seal
- (7) 100% of complete set of wicket gates with bushing for one turbine
- (8) One sets for each type of O-rings, packing and bushings for all parts of one turbine unit
- (9) One sets of wearing ring of each type for one turbine unit
- (10) One sets of facing plate with rubber seal for wicket gates
- (11) Pressure gauges, One each type
- (12) Oil Level gauges, one each type
- (13) One for each type Relays Temperature relay
- (14) One for each type Oil pressure relay
- (15) One for each type Water flow relay and sight
- (16) One for each type Water pressure relay



- (17) One for each type Auxiliary relay
- (18) One for each type Limit switches
- (19) One for each type Shut-off, check and automatic valve
- (20) One for each type any other spares recommended by the Contractor.
- (21) One sets of turbine runner
- (22) One sets wicket gate
- (23) One sets of bronze hubs and cups for wicket gates
- (24) Three sets upper and lower labyrinth rings of runner
- (25) Four sets facing plates of lower rings
- (26) Three sets facing plates of head cover
- (27) Four sets upper and lower labyrinth of head cover
- (28) Three foundation rings
- (29) four bushing of main inlet valves

### 3.8.2 Governor Parts

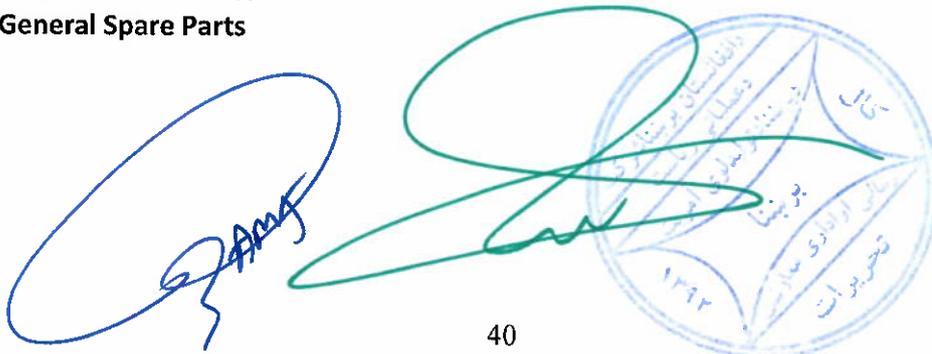
- (1) One restoration cable and all attachments
- (2) One speed signal generator (SSG)
- (3) One speed adjusting motor complete
- (4) One load limiting motor complete
- (5) One sets of transistor sheet (printed card) for each type
- (6) One sets of springs, gaskets, fasteners and washers for one unit complete
- (7) One sets of pilot valves
- (8) One sets of main and auxiliary distribution valves excluding housing
- (9) One complete set of Converter
- (10) One complete set of potentiometers for one unit
- (11) One unloading valve complete for pressure oil pump set
- (12) One pressure oil pump replacement kit, including all moving parts spring and seals (13)  
One air compressor replacement kit, including all moving parts springs and seals any other spares recommended by the manufacturer
- 14) One complete sets of Governor C.P.U. set with customer program installed and ready for replacement.
- (15) One sets of each type of card used in governor controls including DI, DO, AI, AO and interface.

### 3.8.3 Cooling Water System

Two complete set of filters for water cooling systems

One sets valves of each type

### 3.8.4 General Spare Parts



- (1) One sets of ball or roller bearings comprising sufficient bearings
- (2) One sets of gaskets and sealing materials comprising sufficient of each type
- (3) One sets of gauge glasses and inspection window comprising one of each type used
- (4) One sets of filter or strainer replacement elements comprising one for each size
- (5) One complete sets filters of each existing type
- (10) One set of replacement seats, plugs, discs, sleeves or diaphragms (12)  
one set of pressure gauge, relay and switch for each type.
- (13) Any other spares recommended by the manufacturer.

### 3.8.5 Electrical Spare Parts

- (1) One complete sets assembly of each type of relay contactor switch etc.
- (3) One sets solenoid and coil of each type used.
- (4) One complete assembly of each type of pressure and flow switch thermal relay
- (5) One timer rheostat, rectifier and other special devices.
- (6) One sets of lamps and fuses consisting of 500 per cent of the quantity used for one unit.
- (7) One sets of each type of small components such as resistors inductors, capacitors transistors valves transformers, etc.
- (8) Any other spares recommended by the manufacturer

### 3.9 Strength and Quality

The equipment and apparatus shall be designed and manufactured in the best and most substantial and workmanlike manner with material best suited to their respective purpose and generally in accordance with up-to-date recognized standards of good practice. All steel casting and welding shall be stress-relieved by heat treatment before machining and casting shall be stress-relieved again after repair by welding.

Liberal factors of safety shall be used throughout and especially in the design of all parts subject to alternating stresses or shocks.

For the rotating parts of the equipment, the maximum stresses due to runaway speed shall not exceed two-thirds of the minimum yield stresses resulting from a pressure of not exceed two thirds of the minimum yield stress of the material. For all parts of the work subject to headwater pressure, the maximum stresses resulting from a pressure should not exceed the values as per international recognized standard.

For all other load bearing parts of the work under the most severe normal operating conditions the unit stresses in the material shall not exceed from the international recognized standard values.

#### 3.9.1 Stress in Tension

Cast of Iron should be as per international recognized standard.

Cast of Steel as per international recognized standard

Plate Steel for principal should be as per international recognized standard

#### 3.9.2 Stress in Compression

Cast of Iron should be specified in international recognized standard.



Cast Steel should be specified in international recognized standard.

Plate Steel for principal stress Carrying must be specified in international recognized standard.

For other materials, the Contractor shall submit to the Engineer for approval, the maximum Working stresses and the complete specifications of the materials he proposes to use.

#### 4. MHPP General Penstock Bypass valve

Mahipar hydropower plant general penstock main inlet valve's bypass which is located about 335 meters away from power house of the plant, this system is for leveling and difference the pressure between to side of penstock to allowing the water flow into penstock is working and operating manually, it is need to change and installed electric valve for automatic control of bypass also the automatic systems should be energized from separate diesel generator or auxiliary transformer.

### Chapter 2 – Employer's Requirements

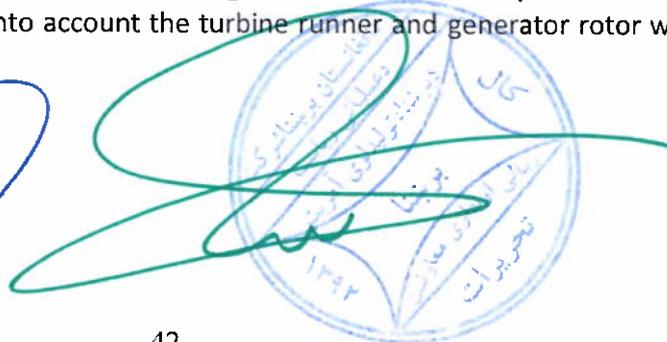
#### 1. Synchronous Generator D650108 (SIEMENS)

The design, supply, installation, pre-commissioning and commissioning of one (1) vertical three phase alternating current synchronous generator, for direct coupling of Francis turbine, complete with excitation equipment and other auxiliary equipment is required. The Tenderer shall submit with his tender the necessary technical brochures, layout and detail drawings for the generator, excitation equipment, and auxiliary equipment to verify compliance with the Specifications.

The Tenderer shall include in his Tender detailed information including sketches and drawings with regards to the construction of all rotor components.

The work shall include detail engineering design calculations, manufacture, shop testing, transport, erection, site tests, commissioning, personnel training and guarantee services for the supplied equipment with technical data as specified below.

The Calculation of the critical speed of the turbine/generator unit shall be performed by the generator manufacture, taking into account the turbine runner and generator rotor weight



and flywheel effect, the two guide bearings and the thrust-bearing flexibility. The necessary turbine data will be provided by the turbine manufacture. The Contractor is solely responsible for coordinating design works for manufacturing.

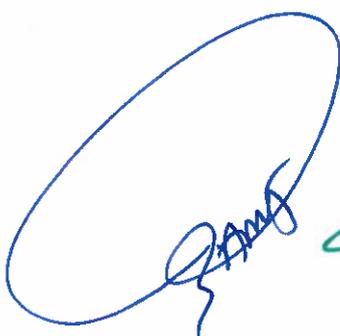
**Note:**

If bidder guarantee the hydro generator power improvement more than existing generating power in their technical proposal, this will be considered in the proposal evaluation criteria as a plus point.

Synchronous Generators				
S.No	Description	Drawing	Technical status	Choice of work
1	Stators		Something dropped between rotor and stator gap of unit#1, and damaged the coils, insulation systems of stator and poles of rotor.	Should be replace
2	Rotors		The rotors of the synchronous machine from installation still now not overhaul and rehabilitate and became damaged and have puffiness.	Need to be replace
2.1	Rotor poles		Not in good condition	Need to replaces

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2.2	Bus bar		From installation still now functioning but not repaired and overhauled	Need to replace (From Al to Cu)
2.3	Wedges		Not in good condition	Need to be replace
3	Shafts		Not in good condition	Need to be replace
3.1	Lower bearing hub		Not in good condition	Need to be replaced
3.2	Middle shafts (Between turbine and generator shafts)		Not in good condition	Need to be replace
4	Thrust bearing		Not in good condition	Need to replaced and redesigned with adjustable supports under the thrust segments.
4.1	Segments of thrust bearing		Not in good condition	Segments are made from Babbitt must be changed to fluoroplastic type.
4.2	Oil cooler systems		Not working properly	Need to be replace
5	Upper generator bearing		Upper bearing is ring type and not working properly	Need to be replace
6	Lower generator bearing		Lower generator bearings are ring type and not working properly.	Need to be replace





7	Slip rings			Need to be replace
7.1	Brushes			Need to be replace
8	Generator cooling systems		Generator cooling systems with pipes, valves and filters are worn out and rusted.	Need to be replace
8.1	Pipes			
8.2	Valves			
8.3	Filters			
9	Oil cooling systems		The oil cooling systems are very old and not Working properly also can't cool the oil.	The oil cooling systems which are very old systems and cannot cool the oil properly, therefore This system is need to be change into new and modern systems.
10	Upper spider			Need to replace
11	Lower spider			Need to replace
12	Brake systems		Not in good condition	Need to be replace
13	Generator oil		Not in good condition	Need to be replace
14	Oil piping and valve systems (7 bar)		Oil, water and air piping and valves systems are very old systems	Oil, water and air piping and valves systems must be
15	Water piping and valve systems (7bar)			

16	Air piping and valve systems (7bar)			Changed from old to new modern systems.
17	Generator protection		The generator protection system is 24 VDC with old type analog relay.	The protection systems should be changed to latest Technology, new and modern as per international recognized design.
18	Oil purifying and handling equipment		Deteriorated	Should be replaced to new and modern one.
19	Generator Excitation systems with all accessories		Old systems which spare parts are not available in market.	Should be replaced to new and modern one.
20	Compressed air systems		Deteriorated	Should be replaced to new and modern
				One.
21	Air conditioning and ventilation systems		Deteriorated	Should be replaced to new and modern one.
22	Firefighting systems		Deteriorated	Should be replaced to new and modern one.
<b>Mechanical workshop</b>				
Supplying of new equipment and spare parts are required				

## 2. Technical Scope for Synchronous Generator

This section specifies the requirement for the 3-phase synchronous generator with auxiliary system. The work shall include detail engineering design calculations, manufacture, shop testing, transport, erection, dismantling, site tests, commissioning, personnel training and guarantee services for the supplied equipment with technical data as specified.

The calculation of the critical speed of the turbine/generator unit shall be performed by the generator manufacture, taking into account the turbine runner and generator rotor weight and flywheel effect, the two guide bearings and the thrust-bearing flexibility. The necessary turbine data will be provided by the turbine manufacture. The contractor is solely responsible for coordinating design works for manufacturing.

### 2.1 Site Condition

Temperature conditions at the site to be taken for design purpose shall be as per supplementary information.

### 2.2 Generator data

$P = 26000 \text{ KVA}$

$U = 10000 \text{ V}$

For more details, please see the drawing package.

The generator shall be withstanding the maximum runaway speed for (acceptable minutes as per IEC or equivalent international standard) after rehabilitation and reverse engineering.

### 2.3 Capacity and Efficiency

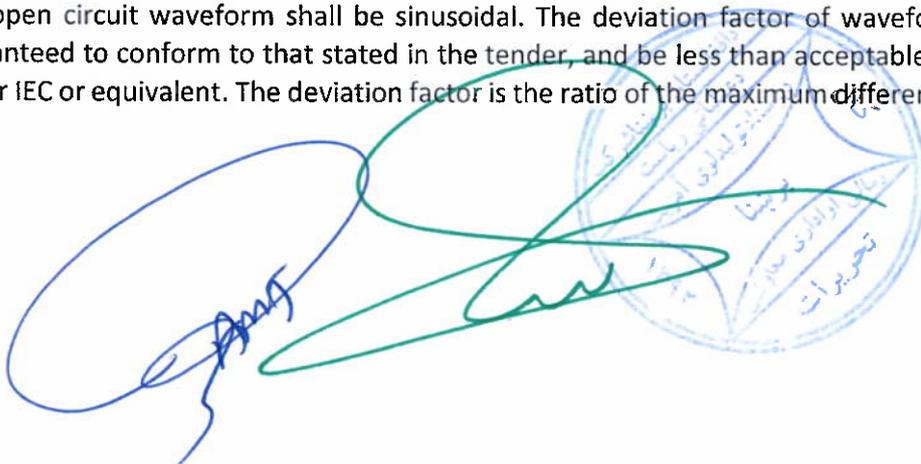
The generator capacity shall be guaranteed after replacement some parts, rehabilitation and reverse engineering. The Tenderer shall provide efficiencies at different percentage value corresponding to IEC or equivalent international standard of rated output at rated power factor, rated frequency, and rated voltage.

### 2.4 The weighted average efficiency

The weighted average efficiency of the generator shall be evaluated as per IEC or international recognized standard.

### 2.5 Wave from

The open circuit waveform shall be sinusoidal. The deviation factor of waveform shall be guaranteed to conform to that stated in the tender, and be less than acceptable percentage as per IEC or equivalent. The deviation factor is the ratio of the maximum difference between

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corresponding ordinates of the wave and of the equivalent sine wave to the maximum ordinates of the equivalent sine wave when the waves are superposed in such a way as to make this maximum difference as small as possible.

### 2.6 Flywheel Effect

The Contractor shall state the flywheel effect in the tender. The generator shall have sufficient flywheel effect (GD2) required by the turbine in such a condition.

### 2.7 Temperature Rise and Maximum Temperature

The limits of temperature rise shall be applied as per IEC or equivalent international standards to the windings of generator, when the generator delivering the rated output continuously at the rated voltage, power factor and frequency, with air temperature entering the generator coolers of not more than acceptable degree of centigrade.

Description	Method of Measurement	Temperature rise
Stator winding	Embedded temperature detector between coils	Acceptable as per IEC
	Resistance	Acceptable as per IEC
Rotor winding	Resistance	Acceptable as per IEC
Core or other mechanical parts where insulated windings are adjacent	Thermometer	Acceptable as per IEC
Exciter winding	Resistance	Acceptable as per IEC

The maximum temperature of each bearing shall be less than acceptable value as per IEC.

Method of Measurement	Temperature
Embedded detectors in metal	Acceptable as per IEC

### 2.8 Insulation

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The windings of generator shall be insulated with class "F" or above. Insulation shall have high basic insulation level suitable to withstand system surges on account of switching surges and lightening surges.

### 2.9 Connections

Each generator shall be star connected with three (3) terminals brought 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. The neutral point of stator winding shall be grounded through grounding equipment as specified in generator neutral grounding section.

### 2.10 Temperature Detectors

Each generator shall be provided with embedded temperature detectors and temperature indicator to be used in common specification with turbine. The resistance type search coils each should be a resistance of 100 ohms as 0°C of platinum element shall be provided for indication on the control board.

Twelve (12) in stator (six as spares).

One (1) in cooling air inlet.

One (1) in cooling air outlet.

Two (2) in thrust bearing.

One (1) in upper guide bearing.

One (1) in lower guide bearing.

One (1) in lower guide bearing oil reservoir.

One (1) in thrust and upper guide bearing oil reservoir.

One (1) in cooling water temperature

And any other parts as recommended by the Manufacture.

### 2.11 Structural Details

The stator frame of the generator will be supported on sole plates laid in the beam concrete foundation. The generator shall be provided with bolts and dowels for fastening the stator frame to the sole plates, and for preserving the alignment between the generator frame and the sole plates. The inside diameter of the stator core shall be large enough so that all removable parts of the turbine can be lifted through the stator with the overhead traveling crane.

The stator frame, supporting the thrust and upper guide bearings combined, shall carry the weight of the rotor assembly of the generator together with the turbine runner, shaft including intermediate shaft, and the unbalanced hydraulic downward thrust on the turbine runner.

The lower bracket, supporting the lower guide bearing, shall carry the unbalanced radial stresses from the rotor and the turbine runner while in operation and the weight of rotor

49

assembly together with the turbine runner and shaft while jacking operation. The bearing bracket shall be designed and constructed so that the bracket can be removed through the stator.

Sole plates and foundation bolts for the stator frame and for the lower bearing bracket shall be furnished by the Contractor. The Contractor shall supply necessary quantity of non-shrink concrete agent to the civil Contractor, who will place concrete for sole plates by non-shrink concrete mixed up according to the Contractor's instruction.

Necessary platforms, stairway, walkways and ladders shall be provided ready access to and for inspection of generator. The arrangement of the generator structure shall be such as to permit removal of the turbine runner upward with the minimum dismantling of the generator.

Provision shall be made for convenient handling of all parts during assembly or dismantling of the unit. Adequate provision shall be made for attaching lifting devices, slings, eyebolts, etc.

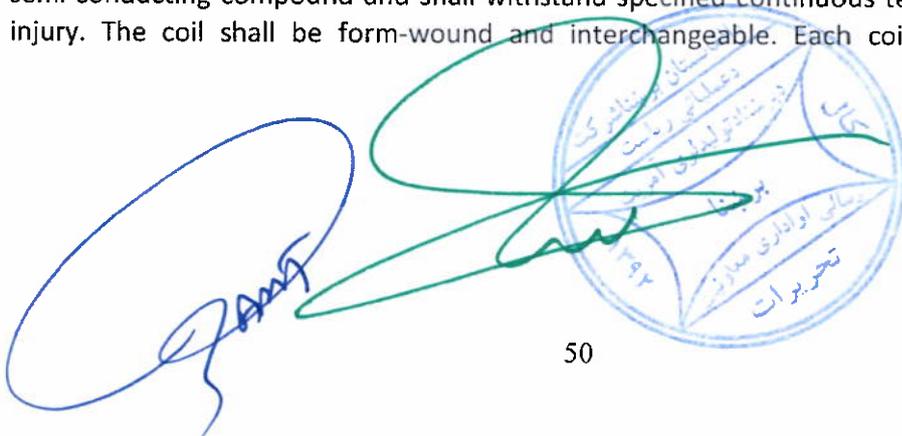
## 2.12 Stator

The stator core shall be built up with thin, high grade, non-aging & a cold-rolled silicon-steel laminations; each lamination coated on both sides, after punching with an insulating varnish or other materials to minimize eddy current losses.

The core laminations shall be adequately keyed, dovetailed or other approved method to the stator frame and securely held in place by clamping flanges at each end. To ensure uniform tightness of laminations, full and final clamping pressure shall be applied to necessary layers of laminations while being stacked. There shall be no perceptible buzzing in laminations during operation. The air ducts shall be arranged in the stator core to make the flow of air smooth and quiet and to minimize windage and friction losses. The stator frames shall be provided with lifting lugs suitable for applying slings for lifting the complete stator by the overhead traveling crane.

The stator winding shall connect as per international standards, line and neutral ends or the winding shall be suitable for termination of the 10 kV bus and power cable respectively. The neutral ends shall be bussed in the generator housing ready for connecting it to the neutral grounding equipment with cable. Terminals shall be copper and shall be of bolt clamp type for connection to the 10 kV bus and power cable terminals respectively.

The coil insulation shall be non-inflammable and be properly vacuum or pressure impregnated with high-grade insulation synthetic resin. The insulation shall become reasonably plastic by the application of heat or shall otherwise be of such nature that the coil can be placed in or moved from slot without injury. The entire coil shall be able to withstand exposure to dampness without injury. The coil shall have adequate corona shielding with a semi-conducting compound and shall withstand specified continuous temperature without injury. The coil shall be form-wound and interchangeable. Each coil shall be properly



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transposed to avoid circulating current within the elements comprising them. All coil ends shall be capped with non-inflammable material filled with suitable compound free from air pocket.

Stator coil conductor shall be electrolytic copper with conductivity not less than the value for annealed copper specified in the approved standard. Connection shall be made with silver or brass soldered.

### 2.13 Rotor

The rotor shall be designed for assembly on the erection bay of the powerhouse. The pole pieces shall be built up of thin laminated steel secured by face plates and tension bolts or thick steel plates grooved on its surface and shall be fastened to the rotor rim by means of dovetails or equivalent and held in position by tapered keys. The keys shall be locked in place on both sides of rotor rim so as to prevent the keys from coming out, in the event they become loose. The field winding shall consist of copper strips of wound edgewise. The turn insulation shall be thoroughly cemented to the adjacent turns. Insulating collars shall be provided at the top and bottom of each field coil and the collar shall be adequately supported at all points, if necessary. The design shall be such as to compensate for shrinkage in the insulation and to maintain adequate pressure on the field coil.

Low resistance damper windings shall be provided in the pole pieces to minimize over voltage and to improve stability due to unbalanced faults. All damper windings shall be of connected type. The damper winding shall consist of hard drawn copper with silver-plated contact surface.

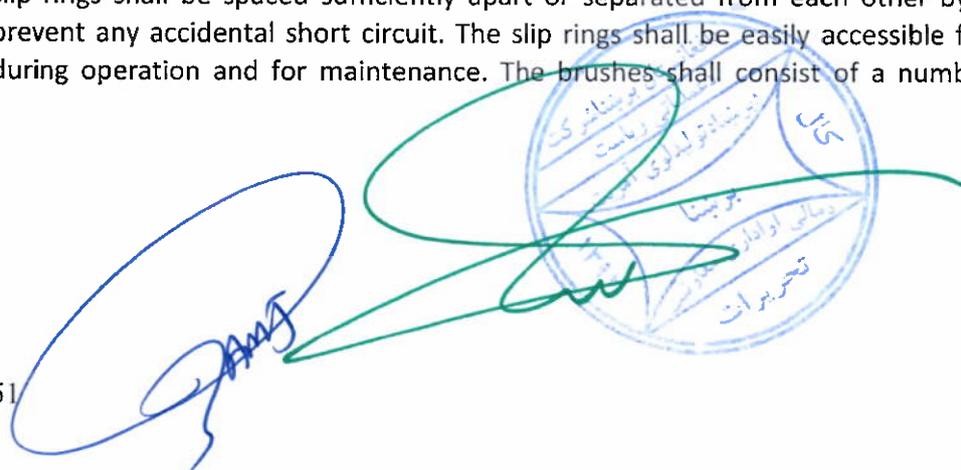
The entire rotor shall be designed to safely withstand all mechanical stresses to be imposed under the maximum runaway speed of the turbine. Special care shall be taken to prevent the end turns from deforming or slipping due to the centrifugal stresses on the interconnections. One set of brake plate shall be provided on the lower side of the rotor on which the brake shoes shall make contact. The wearing surface of the brake plate shall be in segments, which shall be readily removable and renewable. Adequate provision shall be made for dissipation of the heat resulting from the application of the brakes and the expansion of the brake plate segments.

Effective fans shall be mounted at both ends of rotor and suitable air guides shall be arranged for correct circulation of cooling air.

Provision shall be made for balance adjusting weight on the side of rotor.

### 2.14 Slip rings

The slip rings shall be made of stainless steel and shall have helical grooved surface. They shall be well insulated with epoxy glass insulation and designed for use with carbon brushes. The slip rings shall be spaced sufficiently apart or separated from each other by a barrier to prevent any accidental short circuit. The slip rings shall be easily accessible for inspection during operation and for maintenance. The brushes shall consist of a number of carbon



graphite and copper blocks placed in a massive ring. The arrangement and length of the field leads shall enable to reverse the connections to the slip-rings without removing and dismantling the field leads or collector rings. Suitable carbon dust collectors and exhaust systems shall be provided to prevent escape of carbon dust to the generator. Field leads from the collector rings to the field breaker cubicle shall be routed in suitable ducts. The slip rings shall be of the self-ventilated type and accommodated in a separate compartment above the top cover of the generator provided with suitable access doors and windows for easy inspection. Easily replaceable filters shall be provided at the air inlets and outlets to ensure that no carbon dust is released to the powerhouse.

The brush gear shall be designed to enable normal operation for a minimum of six months without replacement of brushes. Easy access shall be provided to the brush gear so that brush pressures can be adjusted or brushes renewed conveniently. The compartment shall be fitted with lighting and temperature monitoring.

### 2.15 Shaft

The generator shaft should be replaced to operate at all speeds including maximum runaway speed and shall be able to withstand short circuit stresses with excessive vibration or distortion. After replacing the contractor shall confirm that shaft will not be permanently damaged due to any kind of deflection or vibration resulting from various mechanical and electrical stresses.

The alignment of shaft shall be checked sufficiently in accordance with International Standards IEEE 810-1994, and the run-out values shall not exceed tolerances specified in the above Standards.

### 2.16 Bearings and bearing hubs

The generator upper bearing with hubs, lower bearing with hubs and thrust bearing with hubs shall be replaced with latest technology systems. The bearings shall be of self-oil lubricated type and both oil reservoirs shall be complete with water-cooling coils. Each bearing shall be capable of operating continuously without injury at any speed from 50 to 100% rated speed, for 15 minutes at any speed from 110% speed to the maximum runaway guaranteed speed and for at least 15 minutes for any speed as low as 10%. The bearings shall also be capable of operating at the rated speed and load without cooling water for at least 15minutes, provided starting at normal operating temperature.

The thrust bearing shall be of the self-equalizing spring or individually adjustable pivoted shoe type with Babbitt-lined thrust pads, and shall have ample capacity to bear the combined weight of the rotating parts of the generator and those of turbine including the maximum

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unbalanced hydraulic thrust on the turbine runner. The thrust bearing shall be designed for normal starting without jacking operation using high-pressure oil injection. The thrust bearing shall be suitable for dismantling in segments, without removal of the generator rotor.

Each guide bearing shall be of segmental type or cylindrical type, and consists of a bearing support or housing and a removable Babbitt-lined bearing shell, surrounded by an oil reservoir.

Each bearing support or housing shall be made of cast steel, or welded-plate steel and shall be designed to support the bearing shell rigidly and transmit the load to the respective bracket.

Lining of guide bearing shall be of suitable high-grade antifriction metal securely anchored in the pads or shell. Each guide bearing shall be suitably grooved for lubricant circulation, and accurately bored for proper fit on the shaft. The lining shall be scraped and polished in the shop to fit properly on the shaft. The guide bearings shall be arranged so as to permit vertical movement of the runner and shaft assembly of an amount required for adjusting and dismantling the generator thrust bearing.

All facilities for servicing the bearings shall be provided, including jacks, lifting eyes, studs etc. necessary to move segments of bearings. Suitable allowance shall be made in the generator design to allow jacking of the generator and turbine rotating parts to facilitate servicing the thrust bearing.

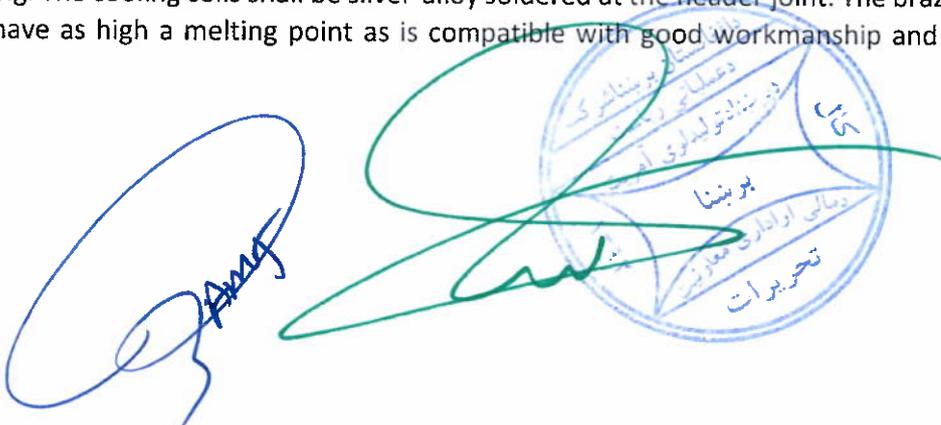
The easily removable eyebolts shall be provided for lifting turbine parts under the lower guide bearing support. All necessary water piping and isolating and control valves shall be provided. The cooling water shall be taken from the cooling water supply system as mentioned.

A flow relay with by-pass valve shall be provided on each discharge line. The cooling water shall be discharged to the tailrace. An isolating valve shall be provided on each discharge line to facilitate servicing. The flow relay shall have suitable contacts for alarm on the control board.

The lubricating oil system shall be designed to use the same oil as in the governor system of turbine. The oil reservoir shall have sufficient volume to hold the oil required under all conditions of operation. All necessary fill and drain connections shall be provided and located for easy access. The terminal ends shall be suitable for easy connection to the oil transfer pump lines for lubricating oil sump tanks specified below.

Adequate provision shall be made for preventing from oil or oil vapor entering the generator air cooling system through the gap between rotating and stationary parts. Two oil vapor filters shall be installed at turbine room floor and the filters shall be cooled by the water.

Cooling coils shall be made of copper tube. The cooling coils shall be separable into two banks for each removal. The coil headers shall have bolted, and gasket covers for easy removal cleaning. The cooling coils shall be silver-alloy soldered at the header joint. The brazing solder shall have as high a melting point as is compatible with good workmanship and complete



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bond development. All connections to the coils shall be made outside the oil reservoir in such a manner that water from a leaky connection cannot drip into either the being or oil reservoir. An oil level sight gauge shall be provided on each oil reservoir and marked to indicate the full range of running oil levels. An oil level switch with contacts for abnormal low-level alarm shall be provided. One (1) temperature detector of dial indicator of the gas filled capillary type shall be provided to sense the hot spot in each bearing, having one set of adjustable contacts suitable for alarm. The indicator shall be located on the turbine control panel, and another type of temperature detector shall be provided to sense the hottest spot in each bearing, having also one set of adjustable contact suitable for tripping circuit. Six (6) resistance type temperature detectors shall be provided; four for the bearing hot spots and the other two for the bearing oil, to indicate the bearing and oil temperatures on the control board in the control room. The temperature detector and the thermometer for bearing hot spot shall be located in the metal of the bearing. The temperature detector shall be 100 ohms at 0°C of platinum element. One (1) water contamination detector for sensing moisture in each bearing oil shall be provided. The detector shall be connected to the protection and annunciation system. Sufficient lubricating oil to fill the generator system and additional 10% shall be furnished with each generator. The type of oil used shall be of the same specification for lubrication of the turbine and the governor oil system as specified in Section.

**Note:** thrust bearing shoes pad must be changed from Babbitt to fluoroplastic, and the thrust bearing should be put on adjustable supporter for adjusting the bearings.

### **2.17 Generator oil (15 T), oil cooling and oil cooler systems**

Design, supply and installation of oil and oil cooling systems also oil cooler is required with all their accessories according to the latest technology as per international recognized standards and need to be installed and compatible with modernized system. The Contractor shall submit the calculation sheet and drawings for approval of the Engineer on the generator oil and oil cooling system also oil cooler and other parts.

### **2.18 Generator (7bar) pipes and valves**

Oil piping and valves systems, water piping and valves systems also air piping and valves systems of generator is old type structure. The systems should be changed by new, modern and compatible systems according to latest technology and international recognized standard. The Contractor shall submit the calculation sheet and drawings for approval of the Engineer on the generator piping and valves systems and other parts.

### **2.19 Generator Cooling**



The image shows two handwritten signatures. The one on the left is in blue ink, and the one on the right is in green ink. Below the green signature is a circular official stamp in blue ink. The stamp contains Arabic text and the number '54' in the center. The text around the stamp includes 'مديرية الكهرباء' (Electricity Directorate) and 'الرياض' (Riyadh). The date '1392' is also visible at the bottom of the stamp.

Design supply and installation of generator cooling systems with pipes, valves, filters and all accessories are required according to international standard (new and modern technology). The systems need to be installed and should be compatible with structures. A sufficient number of air coolers; with sufficient capacity shall be furnished, spaced around the generator stator frame in the ventilation hood for a closed, and re-circulating air cooling system.

The circulation of cooling air shall be by means of the action of axial or radial flow fans attached to the rotor and so designed that all parts of the generator shall have effective contact with the air flow. Each air cooler shall be made of straight tubes with fins to provide adequate thermal conductivity. The headers or water boxes shall be constructed to permit access to all tubes for inspection or cleaning with minimum disturbance to water pipe connections.

Each cooler shall be provided with a drain valve and pipe connection at the bottom which shall allow complete drainage of cooler for inspection, and which shall be connected to a common drainage header draining to the sump pit. Air vents shall be provided at the top of each cooler and other high points in the pressure piping. Each air vent shall be connected to the drainage header. The drain system shall be designed to prevent accumulation of sediment.

The water supply and discharge headers shall be furnished with the coolers. All connections between the coolers and the headers shall be of the flanged type, and a valve shall be provided in the connection between each cooler and supply header so that any cooler can be readily disconnected and removed for maintenance without interfering with the operation of the remaining coolers. The cooling system shall be designed to prevent any accumulation of sediment, and each cooler shall be fitted with a device to individually blow off tubes with compressed air positively. The piping in the generator housing and on other necessary places, where deemed to be necessary, shall be provided with drip-proof protection. The Contractor shall submit the calculation sheet and drawings for approval of the Engineer on the cooling system and other parts. Provision shall be made for measuring the water pressure at the inlet and outlet of each cooler and for measuring the temperature differential of the air and water passing through the coolers to facilitate balancing the cooling when the unit is operated under load. The Contractor shall balance and make all adjustment to the cooling system. A valve on the discharge side of the coolers shall control the flow through each cooler. Any flow adjustment required after the coolers have been balanced shall be made on the common discharge line from the coolers.

A flow relay shall be provided on the discharge line to sense cooling water flow and to provide alarm at the control boards. Each cooler shall be fastened directly to the stator frame or to base frame embedded in the concrete. Lifting lugs shall be provided on each cooler. Pressure drainage pipes conducting cooling water from generator air coolers and bearings to outdoor drain ditch which is constructed by the civil Contractor shall be supplied by the Contractor each cooler shall be designed for safe operation at a maximum water pressure of cooling. The

A blue handwritten signature is written over a circular official stamp. The stamp contains text in Persian, including 'معاونت فنی و اقتصادی' (Technical and Economic Assistance) and 'معاونت فنی و اقتصادی' (Technical and Economic Assistance). The signature is written in blue ink and is partially obscured by the stamp.

coolers shall have sufficient cooling capacity to maintain the temperature of the air leaving the cooler at 40°C or less, with the generator delivering continuously the rated output and cooling water at a temperature of 25°C. Two (2) temperature detectors as which are already specified shall be furnished and installed; one at the inlet and the other at the outlet of air cooler. The cooling water shall be supplied directly from the cooling water supply pump as per Design Drawing.

## 2.20 Generator Housing

The generator shall be furnished with a steel plate housing to cover the generator provided with an access to stator, air coolers, piping, instrument transformers, etc. The outside wall of the generator housing is neatly constructed and sufficiently rigid to prevent objectionable vibrations. Removable plates shall be provided at the top for removing parts of generators. Platform, staircase and stairway shall be provided on the generator housing. All railings shall be chromium plated and minimum diameter of 40mm. The treads and walkway surfaces shall have a non-slip finish. One access door shall be supplied by the Contractor to give easy access to and for inspecting the generator parts in the housing from the generator room floor.

The access door shall be gasket and fitted with a lock approved by the Engineer, having provision for opening the latch from inside whether locked or not. A red color-indicating lamp for distinguishing the operation of generator shall be mounted on the top of the generator.

Six (6) sets of lighting fixtures with guards, two (2) convenience outlets, conduit, and wiring shall be provided for lighting the inside space of the generator housing, and the lighting circuit shall be switched at location near the access door.

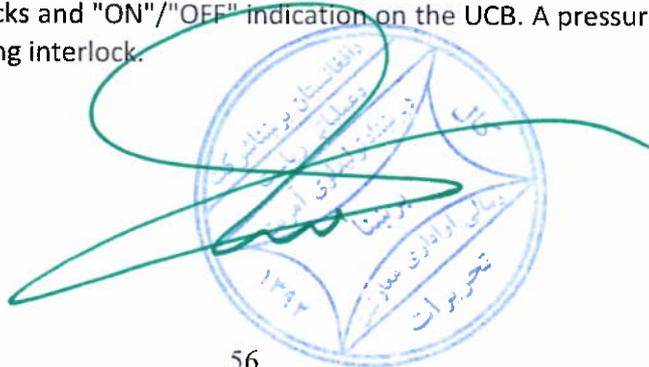
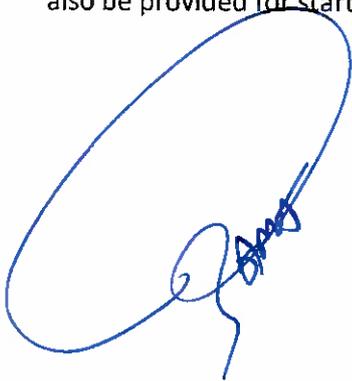
## 2.21 Brake and Jacks

### 2.21.1 Mechanical brake systems:

Mechanically brake systems should be renewed (pneumatic systems).

Pneumatically operated mechanical braking system shall be provided for stopping the unit under normal as well as under emergency conditions. The brakes shall be applied at 25 % of the nominal speed. When the unit is at determined speed, the mechanical braking system shall be automatically activated. Manual operation of the mechanical braking system shall also be provided from the brake control panel and the unit control board UCB.

The total braking time from rated speed to complete stand still for normal and emergency shutdown shall be indicated. The brake shoes shall be provided with suitable, non-asbestos easily replaceable brake lining. The brake shoes shall operate on a polished circular steel brake ring bolted to the bottom of the rotor rim. Compressed air with adequate air pressure shall be used for each unit, of requisite capacity along with pressure gauges, piping and all fittings required for braking of the unit shall be provided and terminated with valves at the generator pits. Each brake cylinder shall be provided with a limit switch with auxiliary contacts to provide starting interlocks and "ON"/"OFF" indication on the UCB. A pressure switch shall also be provided for starting interlock.



The brake system shall be operated locally, from the unit control board (UCB) and the automation and control system (ACS).

### 2.22 Heaters

Electric space heaters of adequate capacity shall be provided inside the generator housing to reduce condensation of moisture on the winding while the generator is shutdown. The space heater shall be of three phases, 400volt, A.C and shall have automatic control system that following auto start/stop sequence along with thermostatic control.

### 2.23 Accessory Leads and Control Cables

Leads and control cables inside the generator housing, slip rings, search coils, controls, space heaters, temperature detectors, speed signal generator (SSG), current transformer secondary and other accessories shall be furnished and installed in steel conduit complete with necessary mounting clamps and fittings. Leads and cables shall be terminated in connection boxes, provided with terminal blocks, placed at one convenient location inside the generator housing. The terminals, leads and cables shall be numbered and color-coded as specified in general specifications. The leads and cables to be used inside the generator housing shall be of nonflammable characteristics.

### 2.24 Excitation systems

The existing excitation systems of Mahipar power plant is simple and old type self-excitation systems which spare parts are not available in market, thus it is necessary to be changed by new and modern excitation systems. The new excitation systems with related parameters, performances, scope and methods of testing, system components shall be in conformity with respective IEC, IEEE or other approved Standards. The excitation system shall be of the static type based on the latest technology and requiring minimum maintenance. The equipment and shall be installed in metal clad cubicles providing easy access for installation, inspection, maintenance, repair and adjustment.

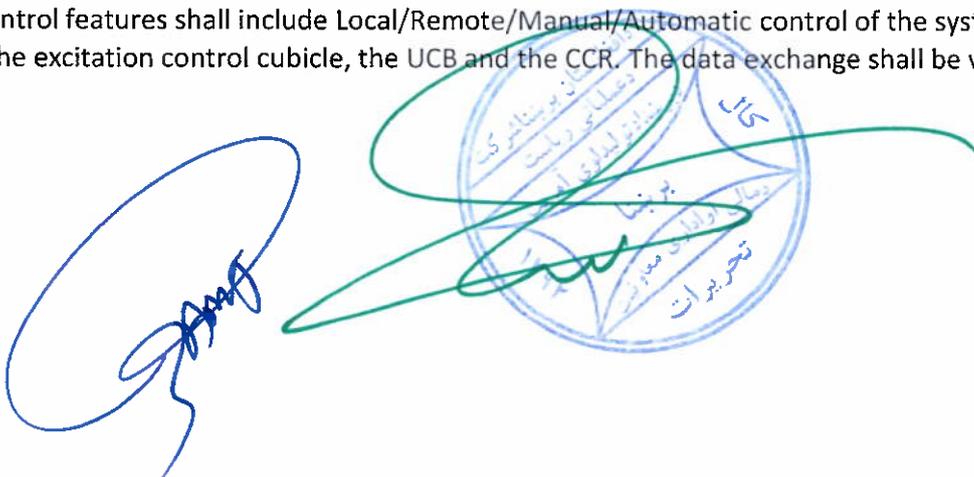
The proposed system shall be optimized and standard product of a competent manufacturer with proven, reliable operation record. The rectifier assemblies shall be directly fed from the excitation transformer connected to the generator main circuit by means of bus ducts or cables.

The excitation equipment shall be designed for supplying without exceeding the continuous rating, ample excitation for the generator operating at its maximum capability at rated frequency, rated power factor and at 105 % rated voltage. Separate current and voltage transducers shall be provided in the excitation cubicles to transmit the generator and excitation current/voltage values to the central control room CCR. The excitation systems shall be suitable for the following operation modes:

Generator operation, over and under excited;

- Joint control
- Line charging

The control features shall include Local/Remote/Manual/Automatic control of the systems from the excitation control cubicle, the UCB and the CCR. The data exchange shall be via bus



system with interface to the automation and control system (ACS). The excitation systems shall include the following features and functions:

- Local, remote, manual and automatic control modes;
- AVR with manual FCR;
- Reactive power/power factor control;
- Joint control with equalizing of stator reactive currents;
- Power system stabilizer (if applicable); □ Stator and rotor current limiter;
- Excitation and impulse current limiter;
- Under excitation limiter;
- Voltage regulation maintaining the voltage within the specified limits at all permissible load conditions;
- Voltage adjustment for synchronizing;
- Impulse blocking in case of overcurrent in the excitation transformer secondary circuit;
- Separate impulse control modules for auto and manual control;
- Follow-up regulation for auto/manual channels to guarantee smooth change-over;
- Field winding temperature measuring system;
- Digital type set point adjusting devices;
- Redundant power supply for the regulator and control modules;
- Transducers for current and voltage measurements;
- Monitoring and protection devices;

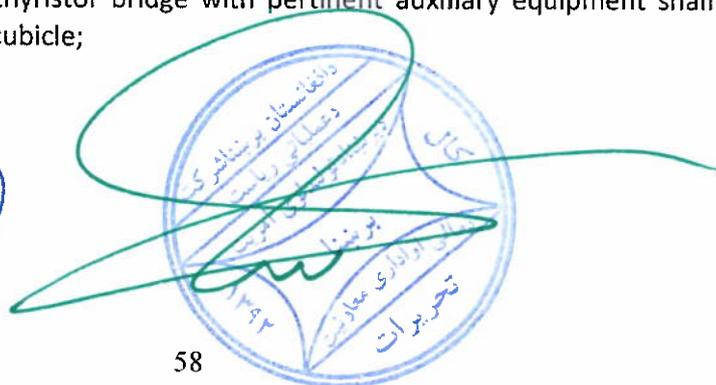
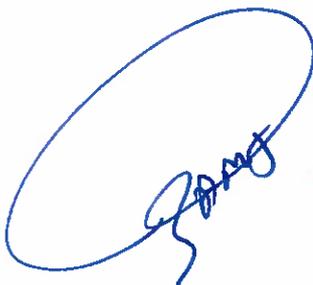
#### 2.24.1 Excitation Transformer

The excitation transformers shall be of the indoor dry type with natural cooling. The insulation level shall correspond to the generator main circuit equipment. The transformer shall be accommodated in a sheet steel cubicle and shall include all necessary equipment for connecting the primary side to isolated phase ducts or XLPE cables and for connecting the secondary side to the excitation cubicle. The transformer shall be supplied with all terminations, temperature monitoring devices and accessories.

#### 2.24.2 Rectifier Assembly

The rectifier assembly shall consist of two or more parallel connected fully controlled three phase thyristor bridges. The rectifier assembly shall meet the following requirements:

- The rectifier assembly shall consist of two or more individual bridges (2x100%, 3x50%) fulfilling the n-1 criterion. The system shall supply the nominal excitation current at rated generator conditions with one bridge out of service. The thyristor bridges shall be 50% loaded. Each thyristor bridge with pertinent auxiliary equipment shall be installed in a separate cubicle;



- The thyristor bridges shall be fitted with monitored fast acting fuses. The thyristors and thyristor fuses shall be mounted on modules designed for individual isolating, easy removal and replacement. The connections to the modules or assemblies shall be bolted;
- Current-limiting fuses shall be provided in each thyristor circuit to isolate the circuit and to protect other thyristors and their fuses from damage if a thyristor fails;
- The components of the thyristor bridges shall be interchangeable. Replacement of individual components shall be possible without disturbance of adjacent equipment;
- For cooling the rectifiers each cubicle shall be provided with a fan, related control and monitoring devices. The air intake openings shall be fitted with appropriate screens and simply replaceable filter mats;
- An automatic generator field flashing system shall be provided taking the power supply from the AC or DC auxiliary supply systems;
- The DC leads between the field breaker and the brush-gear shall consist of insulated copper bars and single core cables, adequately routed and fixed;
- LV control equipment cabling and wiring shall be shielded and isolated from AC and DC power circuits.

#### 2.24.3 Field Circuit Breaker and Field Discharge Equipment

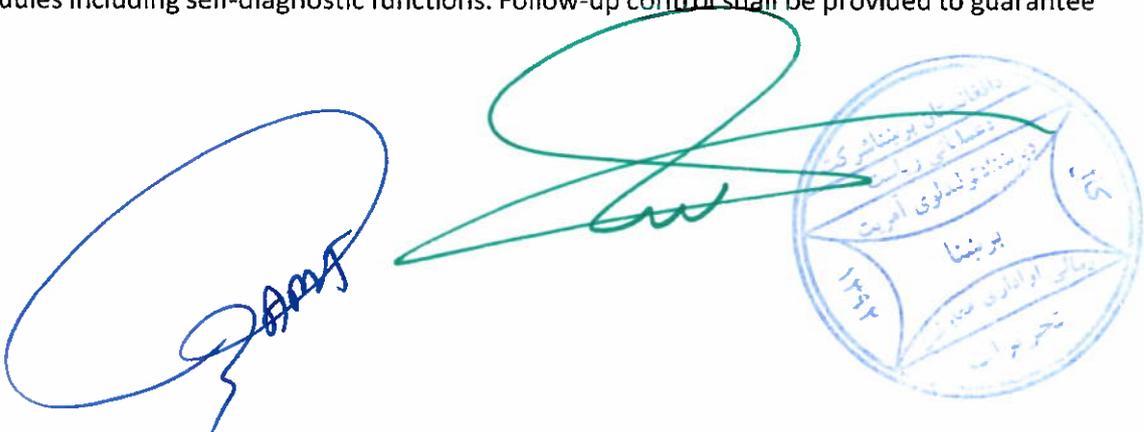
The field circuit breaker shall be an air circuit breaker suitable for use in DC circuits. The breaker's operating mechanism shall be electrically and mechanically trip-free. The field breaker shall be provided for local and remote operation. The breaker shall be rated for the maximum continuous current of the circuit under any of the specified operating conditions of the generator and shall also be capable of interrupting the field circuit successfully under maximum possible short circuit and voltage conditions. The contacts shall be readily accessible for inspection and replacement.

The field breaker shall be provided with a mechanical position indicator and auxiliary contacts of NO and NC type as necessary for control and indicating purposes. In case of normal or emergency shut down the field shall be rapidly suppressed and discharged by means of fully automatic field discharge equipment. The field discharge equipment shall comprise a discharge circuit breaker, a non-linear discharge resistor and control modules for the simultaneous changeover of the thyristor sets from the converter to the inverter mode.

#### 2.24.4 Voltage Regulators

The excitation equipment shall be provided with a system for manual and automatic voltage regulation, excitation control and indication. The excitation system shall be controlled by an automatic voltage regulator (AVR) with integrated manual field current control (FCR). In case the AVR fails the system shall automatically change to the manual control and maintain the actual status. Returning to the automatic mode shall be carried out manually.

The AVR shall be of the digital type regulator with microprocessor-based control, functional modules including self-diagnostic functions. Follow-up control shall be provided to guarantee



a smooth change-over between the different control channels. The AVR shall regulate automatically, accurate and rapidly the generator voltage to a set value by detecting the three-phase voltage signal from the generator terminals. The AVR shall maintain the generator voltage under steady-state load conditions without hunting within  $\pm 0.5\%$  for any load condition within the capability of the generator.

The excitation system complete with AVR shall be capable of:

- Automatic start-up of the unit to be connected to the power system by automatic or manual synchronization;
- Securing stable operation at no-load running of generators;
- Generator operation on the system within the power output from zero to rated capacity;
- Forcing of excitation with per unit current value;
- Field suppression at normal and emergency shut-down;
- Maintaining the pre-set excitation current;
- Limiting the maximum and minimum rotor current;
- Limiting the excitation current sustained overload;
- Maintaining the set point voltage to an accuracy of  $\pm 0.5\%$ ;
- Equalizing of stator reactive currents with generators operating in parallel

The range of the automatic voltage regulating and setting device shall be from 80% to 110% of the rated voltage with the generator connected to the network or in the no-load operation condition.

AVR setting adjustment shall be possible:

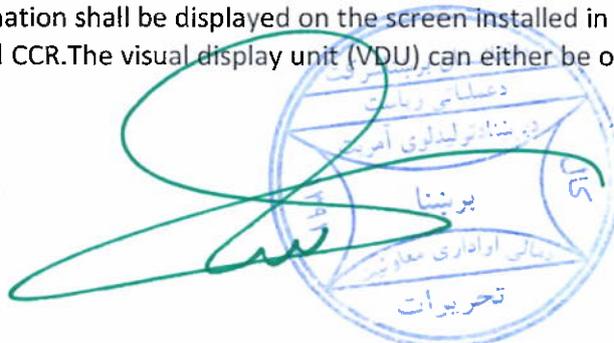
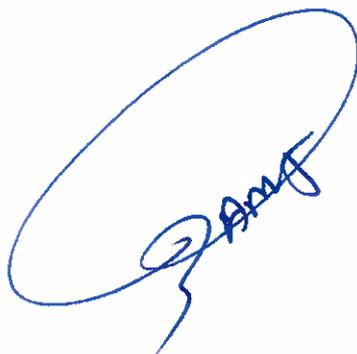
- From the excitation cubicles;
- Remotely from the UCB and the CCR.

The excitation system shall be designed mainly for automatic regulation mode. In case of AVR failure the system shall switch over to the manual mode. For this purpose, each AVR shall include a manual field current control channel (FCR). The manual voltage adjusting device shall allow the adjustment between zero and 110% of the generator voltage which will be necessary for primary current injection and other generator tests.

#### 2.24.5 Control and Protection Equipment

The voltage regulating and excitation control equipment shall be suitable for local, remote, manual and automatic control. Adequate computer-based control systems shall be installed to provide a good overview and to guarantee a reliable and easy operation of the systems.

The voltage regulating and excitation control equipment shall be capable to communicate with the unit controller. All data interchange shall be via communication bus with appropriate interfaces to the ACS. All information shall be displayed on the screen installed in the cubicle and transmitted to the UCB and CCR. The visual display unit (VDU) can either be of the touch



screen type or a VDU with keyboard. Interfaces for the ACS and the commissioning tool shall be provided.

The system shall be suitable for "tele diagnostic". Field winding temperature measuring systems with local and remote indication in the UCB and CCR shall be provided.

The excitation equipment shall be provided with at least the following protection features:

- Limitation of excitation current and forcing level;
- Transformer overcurrent and temperature protection;
- Loss of field protection;
- Overcurrent and short-circuit protection for the thyristors;
- Over and Under voltage protection for thyristors and field windings;
- Additional protection devices proposed by the Tenderer shall be listed in the price list.

#### 2.24.6 Current Transformers

Current transformers of the dry synthetic resin type with separate secondary cores for metering and for protection shall be installed for the excitation transformers.

#### 2.24.7 Line Charging System

The excitation systems shall be fitted with all hard and software necessary for fully functioning systems for manual and automatic operation of transmission lines charging etc.

#### 2.24.8 Cubicles

The excitation equipment shall be accommodated in a cubicle assembly consisting of:

- Field breaker and field discharge cubicles;
- Rectifier cubicles;
- AVR and excitation control cubicles; ▪ Excitation transformer cubicle.

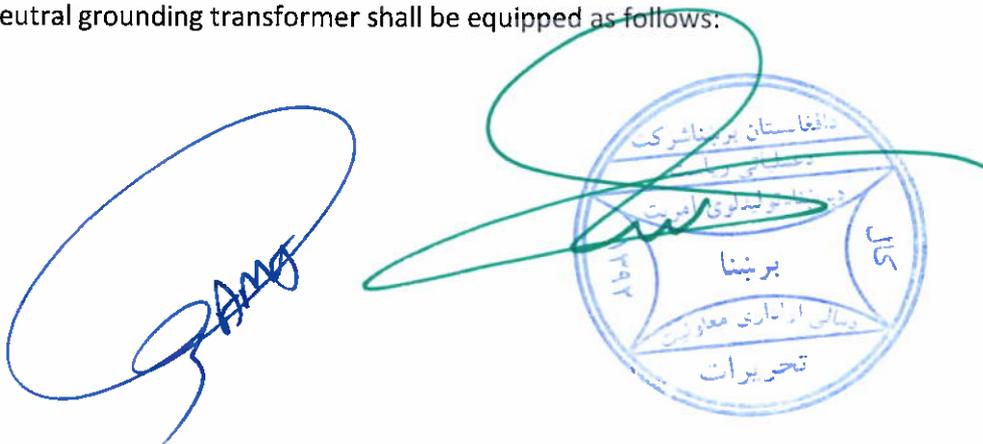
#### 2.25 Surge Absorber

The generator shall be provided with a suitable surge absorber of draw out type, consisting of condenser and lightning arrester. The surge absorber shall be installed in a sheet steel cubicle.

#### 2.26 Generator Neutral Grounding Equipment

Generator # 1 shall be grounded through a single-phase transformer and a loading resistor connected to the secondary terminals of transformer. The generator neutral leads shall be connected together inside the generator housing and brought out for connection to the neutral grounding equipment by a single-conductor cable. The neutral grounding equipment shall consist of a single-phase dry molded type transformer, a single pole-disconnecting switch, and a loading resistor complete with all accessories. The neutral grounding equipment shall be accommodated in a sheet steel cubicle and located near the generator housing. Each cubicle shall be of rigid, self-supporting, indoor use type with a door for access to the equipment. The neutral grounding transformer shall be of single-phase, self-cooled, indoor use, dry molded type.

The neutral grounding transformer shall be equipped as follows:



- One (1) single-phase, dry type transformer with adequate voltage ratio and rating. The insulation class of the primary side shall be in compliance with the generator phase to ground voltage and the rating shall suit the requirements of the loading resistor.
- One (1) loading resistor with an insulation level of  $\geq 600$  V and a current rating corresponding to a primary current equal to the capacitive current of the undisturbed system but not exceeding 10 A.
- One (1) sheet metal cubicle of IP 42 protection class with space heaters and hinged, lockable front doors.
- One (1) cable connection between generator neutral point and the primary side of the earthing transformer. The cable voltage rating shall be in compliance with the transformer primary voltage

### 2.27 Fire Protection Equipment

One set of automatic water jet protection system shall be provided for generator units, the water piping for the fire protection system shall be made separately. The water reservoir shall be situated outside the underground power house. The fire protection system shall be complete with water piping, ring headers discharge nozzles, temperature detectors, and other necessary components.

At least (2) smoke detectors and four (4) temperature sensing detectors shall be located at strategic points on and around each generator in the housing. The temperature detectors shall initiate an alarm whenever the combination rate of rise or fixed temperature detectors. They shall close the contacts either on rapid rise of temperature or of fixed temperature setting. Contacts shall automatically be reset after rate-of-rise operation. Two ionization detectors for each generating room, shall be provided. The detectors shall detect products of combustion without being dependent upon presence of either heat, smoke or flame. It shall function on ionization chamber principle and shall have no moving parts. It shall be possible to check or adjust the sensitivity to suit local conditions. A pilot LED shall indicate the state of detector. The electrical control shall be arranged to automatically discharge water jet into the housing in the event of operation of either temperature detector and/or smoke detector or other method approved, plus operation of differential relay on the generator.

Inspection mode shall be possible to activate by pressing a switch/handle so that no release occurs during this mode. Manually locking of valve should also be provided. The differential protection activation of the fire protection should use a timer element in order to avoid false/unnecessary release during 15% out of phase synchronization.

The detection and control lines as well as the alarm release shall be permanently controlled by means of closed-circuit devices, supervising wire breakage, short-circuits and according to model used, ground faults. Besides automatic detector lines manual station lines shall be

provided near each generator room. The push button/switch (manual station line) to be enclosed within break-glass type housings.

Sufficient number of flash-lights and horns shall be connected in important locations of the plant to annunciation the fire protection in case of alarm. The manual control for discharge of water jet shall also be available both, local on the automatic fire extinguisher cabinet and remote from the control room at the power house. Further the water jet shall be applied only after electrically isolation of the generator during fire situation. Two switches shall be provided to annunciate the operation of water jet discharge. One switch shall be provided for the power house to control the shut-off operation of the air circulation for the power house fan system, which will be provided under another contract.

The contacts for status and fault indications shall be provided for those indication on the control board and the contractors shall design the control and annunciation for the fire protection equipment.

## 2.28 Control System

### 2.28.1 Unit Auxiliary System

The essential auxiliaries associated with the generator unit shall be connected to a 400-volt A.C. 3-wire or 4-wire motor control center, other nonessential auxiliaries shall be connected to an A.C. panel. The neutral point of 400-volt system is to be solidly grounded.

### 2.28.2 Control Facilities Required

All control, indication and protection circuits shall be operated by a 220 V D.C. system, except for motor controls by 230V A.C.

The normal method of starting and stopping the generator unit # 1 shall be made by automatic equipment initiated by an operator in the power station control room. After positioning the "Local – Auto/Local – Manual", control selector located on turbine control will be operated by independent control switches on the turbine control panel. Facilities are required for performing each of the following operations automatically from the central control room (CCR) and manually from the unit control board (UCB).

- (1) Opening of the turbine inlet valve after annunciation has indicated to the operator, the operation of certain functions, starting of the turbine, bring the unit to synchronous speed, and application of generator field excitation.
- (2) Synchronizing of the generator.
- (3) Normal stop of the turbine unit.
- (4) Emergency or quick stop of the turbine unit under all fault conditions.
- (5) Emergency shut down by a manual switch operating an independent lockout relay.

### 2.28.3 Automatic Starting and Stopping Control Features

The automatic starting and stopping schemes shall be such that it is possible to change over from "Automatic control" to "Manual control" or vice versa while the machine is running, or standing without changing the status quoted, safely. No solenoids or coils shall be left

The image shows two handwritten signatures. The one on the left is in blue ink, and the one on the right is in green ink. To the right of the green signature is a circular official stamp in blue ink. The stamp contains text in Urdu: 'دانشگاه پوینا' (University of Poonja), 'معاونت تعلیم و تربیت' (Department of Education), 'مفتی محمد رفیع' (Mufti Muhammad Rafeeq), 'پوینا' (Poonja), 'دعوتی ادارہ تعلیم و تربیت' (Department of Religious Education), and 'تھتہ پوینا' (Thath Poonja). There is also a date '۱۳۷۵' (1375) written in the stamp.

energized continuously as far as possible, while the machine is either running or standing. The control system shall be such that temporary interruptions of the main 220-volt D.C. Supply shall not affect the running or standing condition of the machine.

#### **2.28.4 Automatic/Manual Synchronizing Equipment**

One common set of automatic/manual synchronizing equipment shall be provided in a sheet steel panel suitable installing in the control room. The automatic synchronizing equipment shall be designed to permit either manual or automatic control of turbine speed, generator voltage, and breaker closing through synchro check relay, for the purpose of connecting a generator to a running system with a minimum of disturbance to the machine or the system. The equipment shall include an automatic synchronizer, a voltage balancing relay and a speed matcher. Interlocks shall be provided to ensure that only one generator is connected to the synchronizer at a time.

The manual synchronizing device shall be installed on the control desk or suitable locations and shall consist of following meters.

- Two (2) voltmeters
- Two (2) frequency meter
- One (1) phase angle meter along with synchro check relay

The voltage supply shall be fed from potential devices and potential transformer connected to 110 kV buses and generator circuits as shown on the main single line diagram.

#### **2.28.5 Automatic Control Panel**

Generator 1 shall be provided with a sheet steel panel of the same construction and appearance as the automatic synchronizing equipment panel, and shall be equipped with all necessary relays and instruments for automatic control and shall be installed in the control room.

#### **2.28.6 Instruments**

The following instruments shall be provided for mounting on each turbine control panel:

Three (3) dial thermometers for generator bearings.

Two (2) dial thermometers for inlet and outlet air temperature of the generator cooler. Two (2) common temperature recorders, to be used with the temperature detectors, shall be furnished by the Contractor for each unit.

#### **2.28.7 Protection**

Protective scheme shall include all the necessary relays, instrument transformers and connections for the electrical protection of the generator and conductors as shown on the main single line diagram.

The Contractor shall also include in his automatic control system all necessary devices for shutting down the machine on the occurrence of each of the following conditions:



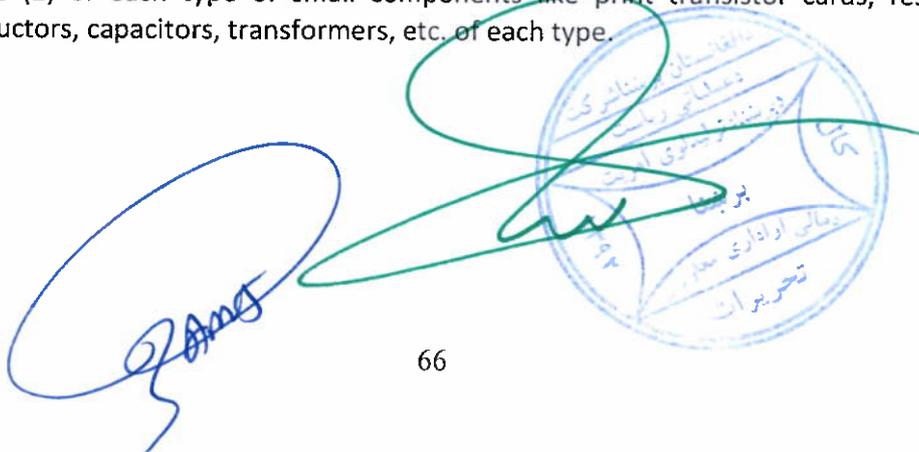
The special tools and special equipment shall include but not limited to the following:

- One (1) set of all complete wire ropes for assembling and dismantling of one unit of generator, with hunger.
- One (1) complete set of casehardened wrenches and any special wrenches, and standard and special tools for the generator, all marked with size and purpose, and mounted on a suitable shadow board.
- One (1) set of special lifting device for bolting to the generator rotor or shaft and attaching to the powerhouse crane lifting hooks or beam.
- One (1) pedestal with sole plate for rotor erection. □ Others recommended by the manufacturers.

### 2.31 Spare Parts

The following spare parts shall be furnished and quoted separately for unit # 1 in the main equipment.

- One set of upper and lower guide bearings.
- One complete set of thrust bearing runner springs and shoes.
- Ten (10) % of half-stator coils, with all supplies required for installation, plus 10% extra wedges and materials for unit # 1.
- One pair of generator field pole with coil and core including necessary materials for insulation.
- One set of thyristors comprising one third of the total quantity required for one bridge.
- One sets of spare parts for the voltage regulator and excitation control equipment including brushes for auxiliary motors, of relays, contactors and control elements of each type.
- One (3) dial thermometer, one for thrust bearing, one for generator upper guide bearing, and one for air cooler for unit # 1.
- One sets of oil level sight gauge.
- Three complete sets of brake shoes.
- One complete sets of segments of wearing brake plates.
- One assembly of automatic synchronizer for each unit.
- One of relays, contactors, switches, etc. of each type for unit # 1.
- Complete assembly of flow relays, timers, rheostats, rectifiers and other special device of each type for unit # 1.
- 500% of lamps and fuses consisting of the quantity used for unit # 1.
- One (1) of each type of small components like print transistor cards, resistors, inductors, capacitors, transformers, etc. of each type.



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- One (1) solenoid coils of each type for unit # 1.
- One (1) complete set of fire detectors for fire extinguisher. □ Other spare parts as recommended by the manufacturers.

## 2.32 Tests

### Tests at Works

#### 2.32.1 Routine tests

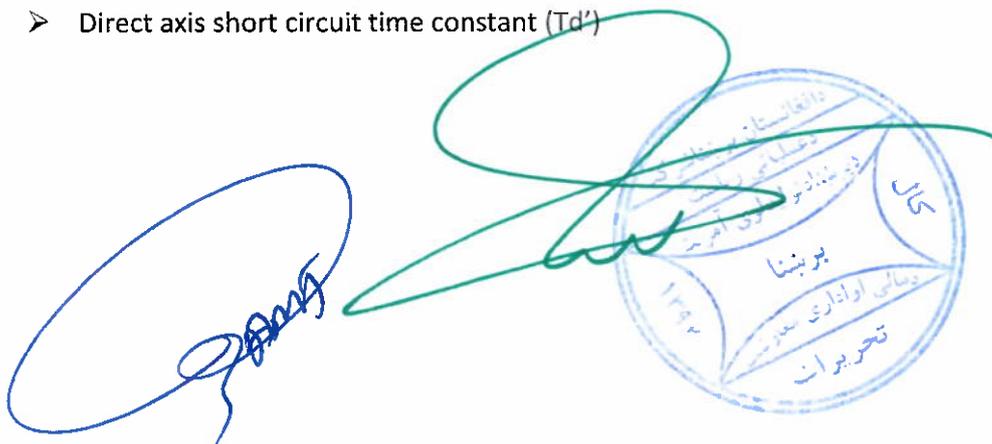
generator shall be subject to the following tests:

1. Check of the dimensions for stator.
2. Resistance measurements for field coils
3. Insulation resistance measurement.
4. High voltage test for stator and rotor.
5. Loss angle test for stator.
6. Hydrostatic test.
7. Secondary excitation curves and internal resistance of current transformers to be used on relaying service.
8. Shaft alignment check/run out.
9. AVR & Exciter test

#### 2.32.2 Special tests

The generator shipped first shall be subjected to the following tests after assembly at the manufacturer's plant:

1. Characteristic curves of main generator for open circuit (up to 125% rated voltage) and short circuit (up to 125% rated current) performance and zero power factor saturation.
2. Determination of reactance and time constants: ➤  
Synchronous reactance, direct axis ( $X_d$ ).  
➤ Quadrature axis reactance ( $X_q$ ).  
➤ Transient reactance, direct axis ( $X'_d$ ). (\*) ➤ Transient reactance, quadrature axis ( $X'_q$ ).  
➤ Sub-transient reactance, direct axis ( $X''_d$ ). (\*) ➤ Sub-transient reactance, quadrature axis ( $X''_q$ ).  
➤ Armature short-circuit time constant ( $T_a$ ). (\*)  
➤ Zero sequence reactance ( $X_0$ )  
➤ Negative sequence reactance ( $X_2$ )  
➤ Positive sequence reactance ( $X_1$ )  
➤ Direct axis transient open circuit time constant ( $T_{do}'$ )  
➤ Direct axis short circuit time constant ( $T_d'$ )



- Direct axis sub transient open circuit (o/c) time constant ( $T_{do}''$ ) ➤ Direct axis short circuit (s/c) time constant ( $T_d''$ ) ➤ Capacitance of winding.

(\* Sudden three-phase short circuit at rated speed with approx.20% rated voltage separate excitation.

3. Determination of losses and calculation of efficiencies.
4. Phase sequence test.
5. Phase balance test.
6. Temperature rise test.
7. Wave form test at no load, rated speed and rated voltage.
8. Retardation tests to determine flywheel effect (GD2) of rotation parts.
9. Shaft voltage measurement.
10. Characteristics of excitation system, including AVR.
11. Shaft throw check.
12. Vibration measurement.
13. Resistance measurement of windings.
14. Measurement for cooling water discharge.
15. Measurement of cooler capacity.

### 2.32.3 Tests for associated equipment

The associated equipment for the generator shall be subject to the following tests:

#### Surge absorber:

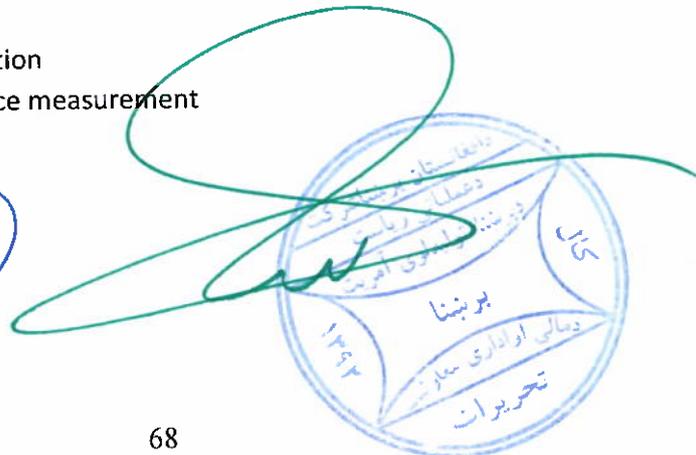
- ✓ Mechanical inspection
- ✓ Power frequency spark-over voltage test (arrester only)
- ✓ 100% impulse spark-over voltage test (arrester only)
- ✓ Insulation resistance measurement (arrester only)
- ✓ Capacitance measurement (condenser)
- ✓ Loss angle measurement (condenser)
- ✓ High voltage test (condenser)

#### Neutral grounding device

- ✓ Mechanical inspection
- ✓ Resistance measurement
- ✓ Temperature rise test
- ✓ High voltage test

#### Fire protection equipment

- ✓ Mechanical inspection
- ✓ Insulation resistance measurement



- ✓ High voltage test
- ✓ Sequential operation test
- ✓ Detector tests

**Excitation control cubicles and automatic control panel**

- ✓ Mechanical inspection
- ✓ High voltage test
- ✓ Sequential operation test for each module
- ✓ Meter and relay tests

**2.33 Tests at Site**

The equipment supplied and installed shall be tested in accordance with the requirements of the "Preliminary Tests" and "Tests on Completion" specified in General Specification. Black start run of machine shall be carried out at site. Performance guarantee test shall be carried out the unit # 1 at site after Test on Completion works. Performance guarantee test is conducted to verify the combined efficiency of turbine & generator (to find out the turbine & generator losses).

**Chapter 3 - Employer's Requirements**

**1. Ancillary Equipment**

The ancillary equipment to be supplied and installed at the power station is as follows:

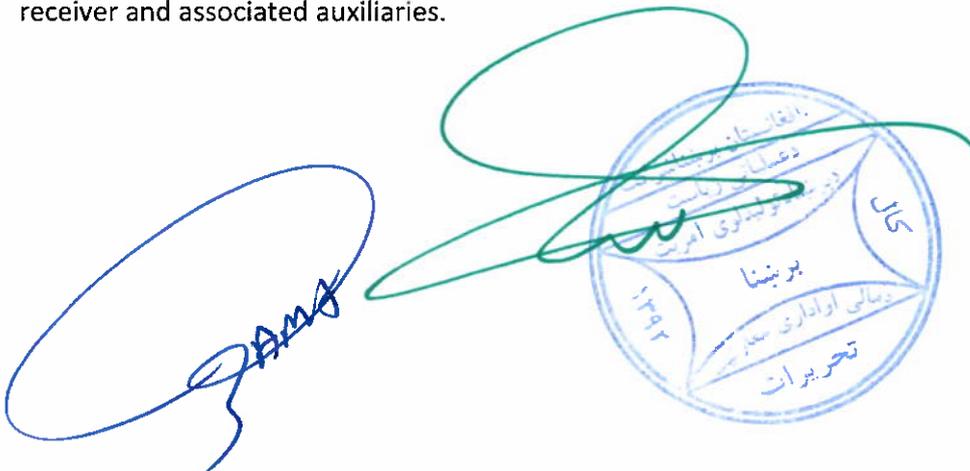
- ✓ One (1) lot of water drainage system
- ✓ One (1) lot of compressed air system
- ✓ One (1) lot Air Conditioning and Ventilation
- ✓ One (1) lot Fire Fighting System

**4. Compressed Air System**

The different air pressure systems are available in the MHPP these systems are used for circuit breaker, governor control, cavitation solving problems in turbine draft tube, braking systems, and gate valve control systems. Compressed air systems shall be provided in the powerhouse cavern. The compressors and associated equipment shall be located on the turbine floor.

The Works shall consist of the following:

- One high pressure compressed air system including two compressor sets, one air receiver and associated auxiliaries.



- One low pressure compressed air system including two compressors, one air receiver, and associated auxiliaries.
- Piping and valves for compressed air distribution in the powerhouse. □ Compressor's air tank for air storing with sufficient capacity □ Local control boards.
- First lubricant filling plus a 10% reserve.
- Tools and devices.
- Spare parts.
- Submission of documents.

**Notes:**

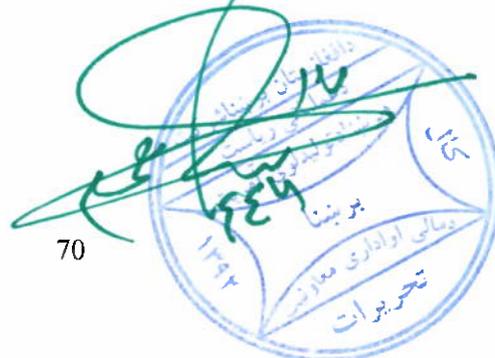
- The Works shall include all locally installed instruments, and all control and alarm devices required for manual or automatic, local control. The internal wiring of the switchboard, the cabling from external instruments and switches to the local switchboard terminals, and connecting the control cables to the switchboard shall be included. External terminal boxes shall be designed to IP 67.
- The supply shall, include high pressure compressed air feeders. These feeders shall be provided with terminal branches for connection to the oil accumulators of the governor.
- The supply shall include a 6 – 8 bar air feeders with terminal branches in the vicinity of the generator brake control panels.

**4.1 System Description, Characteristics and Operating Condition**

**4.1.1 High Pressure System**

The design pressure of the high-pressure system shall be at least 130% of the maximum operating oil pressure of the oil/air accumulators of the governor. The high-pressure system shall consist of the following components:

- Two (2) two-stage or three-stage, motor-driven, reciprocating compressors, one as the duty compressor, the other one as stand-by unit. The capacity of each compressor shall be such that the required air capacity of one governor pressure oil accumulator and one air receiver can be prepared within 8 (eight) hours.
- One air receiver for fast replenishment of air into the air/oil accumulators. Capacity shall be approximately 1 m<sup>3</sup>. The air receiver shall be provided with pressure gauge, safety valve, check valve, all necessary isolating valves, drainage valve, and a manhole. The supply pipe to the air receivers shall incorporate an air cooler/drier with by-pass line and automatic drain.



- III. All necessary piping, valves, solenoid valves, pressure switches, alarms, system protection and instrumentation to provide a complete system. The two compressors, simultaneously in operation, shall be able to charge the air receiver and all oil/air accumulators in less than four
- IV. Hours from the atmospheric pressure to the nominal pressure.

#### 4.1.2 Low Pressure System

It shall consist of the following components:

- I. Two screw type, motor-driven compressors, one as the duty compressor, the other one as standby.
- II. One air receiver sized 1.5 m<sup>3</sup>. The receiver shall be provided with pressure switches to switch the compressors on and off, and to trigger an alarm on the Unit Control Board in case of excessive loss of pressure. The receiver shall be provided with pressure gauge, safety valve, check valve, all necessary isolating valves, drainage valve, and a manhole. The supply pipe to the air receiver shall incorporate an air cooler/drier with by-pass line and automatic drain.
- III. The piping for distribution of low pressure compressed air shall be routed to the following points:
  - ✓ To the air tanks of the mechanical generator brakes located on the generator floor.
  - ✓ The following tapping points for supply of service air:
    - Three (3) points at the MIV floor i.e., one near to each main inlet valve,
    - Three (3) points at the turbine floor i.e., one near to turbine, and one in the compressed air plant.
    - Three (3) points at the generator floor i.e., one near to each generator; □ Two (2) in the power station workshop and store.

One compressor alone shall be able to fill one air receiver from atmospheric pressure up to rated pressure of 8 bars within two (2) hours. One compressor shall be able to recharge one air receiver from minimum operating pressure to maximum service pressure in less than five (5) minutes.

#### 4.2 Quality Assurance

##### Reference Standards

Standards for compressed air systems are set forth in ASME Pressure Vessel Code. As an alternative, relevant chapter of EN 13445, "Unfired pressure vessels", can be used as a reference.

##### Design conditions



## Design Stress

- Under usual loading, the maximum equivalent stress shall not exceed 50% of the yield strength.
- Under unusual loading and hydrostatic test pressure, the maximum equivalent stress shall not exceed 70% of the yield strength.
- The plant shall be designed to safely withstand the earthquake forces of 0.35 g acting in any directions.

### 4.3 Shop Tests and Inspection

The Contractor shall prepare a table, listing all components to be tested and the tests to be performed. The Employer reserves the right to request additional tests if necessary. Test certificates for materials and equipment shall be provided in triplicate to the Employer. Shop tests shall include the following:

- Hydraulic pressure tests on all components under internal pressure. The test pressure shall be 1.5 of the design pressures.
- Routine tests on purchased equipment.
- Insulation tests, operating tests, heating tests, load tests, etc. on electric motors, and other electrical and mechanical components.

All plant shall be assembled for the inspection of functional tests. Exceptions may be permitted if approved by the Employer. All parts shall be correctly doweled and matchmarked to facilitate assembly at the Site. The Contractor shall give the Employer notice in writing of the date and place of inspection and testing not less than two weeks before the parts are ready, and give the Employer full facilities for conducting or witnessing the tests.

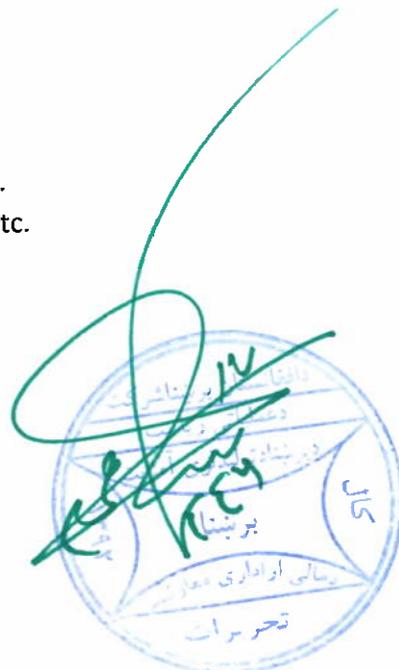
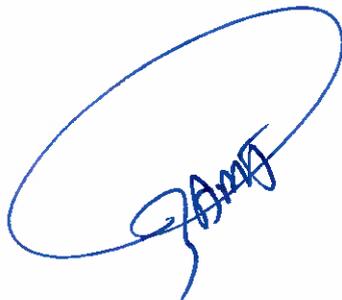
Three copies of the test reports shall be provided to the Employer.

At least the following components shall be assembled and presented to the Employer:

- Compressor sets.
- Control valves.
- Non-return valves.
- Safety valves.
- Air tank
- Local control switchboard.

The tests shall include the following:

- Check of conformity with approved documents.
- Operation of electric motors, limit switches, etc.
- Hydraulic pressure test
- Setting and calibration of safety valves.
- Seal leakage check.



When the plant has passed the tests to the Employer's satisfaction, he will confirm that it is satisfactory and that it can be disassembled, painted and packed for shipment.

#### 4.5 Guarantee

##### a) Guaranteed Performances

The Contractor shall guarantee the following:

- The capacity of the high-pressure compressors proved by the charging time.
- The capacity of the low-pressure compressors proved by the filling time. b)

##### Penalties

- The Employer reserves the right to reject compressors unable to fulfil their capacity.

#### 4.6 Products - Components and Sub-Assemblies

##### Compressors and Air Vessels

The compressors shall be direct-driven, water or air-cooled. They shall be equipped with roller or ball bearings. The cylinders of reciprocating compressors shall be pressure oil lubricated using directly driven lubrication pumps. Compressor and motor shall be mounted on a common base frame. Compressor and motor bases shall be equipped with vibration absorbers. The motors shall be A.C. driven, class IP 54. The air vessels shall be of welded steel plate and designed, manufactured and equipped in accordance with ASME Code "Rule for Construction of Pressure Vessels" or EN 13445, "Unfired pressure vessels".

##### Valves

###### (a) Gate Valves

Ring seal type gate, cast or forged steel body, non-corroding sealing face and stem, flanged ends above DN 25, non-rising stems, solid wedge. Motor-operated valves shall have a fast opening/closing. (b) Globe Valves

Cast or forged steel body with flanged ends above DN 25. The rotor shall be made of stainless steel. Motor-operated valves shall have a fast opening/closing.

###### (c) Non-return Valves

Non-return valves shall be designed to avoid reverse flow without time delay. Any fluttering of the valve closing device shall be avoided.

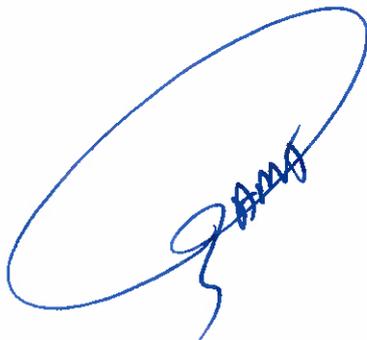
##### Valve Actuators

Self-contained with a high torque motor, power gearing, limit switches, torque limit switch and auxiliary hand wheel for manual operation.

##### Piping

The piping shall consist of seamless stainless-steel pipes, with stainless steel fittings if required and subdivided with maintenance valves on major branch pipes and dismantling flanges on long stretches.

Pipes above DN 25 shall be joined by flanges or welding. All weld seams shall be treated to prevent corrosion. The piping shall be so arranged that no excessive forces or movements due



to temperature movement can occur, and provisions shall be made to prevent excessive vibrations or pulsations.

#### **Local Control Board**

The control board shall be wall-mounted adjacent to the compressors, and for protection class IP 67. It shall accommodate the control equipment, a set of terminals with 20% spare arranged on a terminal strip, electric switchboard heating, vapor-tight type lighting inside of the switchboard to facilitate maintenance work, and a 220 V, 50 Hz socket outlet.

The control equipment shall include the following components:

- Duty/standby selector switches for high pressure (if required) and low-pressure system. Key-operated selector switches, three positions, "Off", "Manual" and "Automatic", for the high-pressure system and low-pressure system.
- Push buttons "On" and "Off" for all compressors.
- Push buttons "Opening" and "Closing" for all electrically operated valves.
- Indication lamps "On", "Off" and "Failure" for all compressors, and "Open", "Closed" and "Failure" for each electrically operated valve.
- Indication lamps for pressure high, normal, low for each pressure system.
- Operating hour counters for each compressor.
- Outputs of individual alarm signals for recording by sequence recorder (sequence recorder not included).
- Separate collective alarm outputs for the high-pressure system and the low-pressure system.

#### **4.7 Special Tool and Devices**

4.8 One complete set of all special tools, necessary for the assembly, disassembly and maintenance of the compressed air system shall be provided.

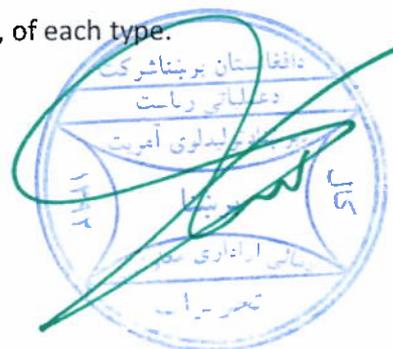
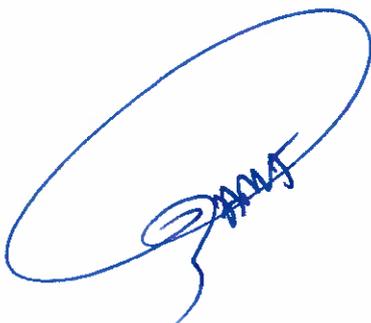
#### **4.9 Spare Parts**

##### **General Spare Parts**

The Contractor shall supply two (2) sets of Wear and Tear items and one (1) set of customary spare parts for "Identical Assemblies". In addition, the following spare parts shall be provided:

##### **Special Spare Parts**

- One control valves of each type.
- One check valves of each type.
- To measuring instruments of each type.
- One safety valves of each type.
- One pressure switches of each type.
- One sets of piston rings of each type.
- One sets of solenoids or motors for valves, of each type.



- One pressure transmitters of each type.
- One sets of delivery and suction valve for compressors of each type. □
- One filter inserts of each type.

All spare parts should be packed and protected for an in-door storage time of at least 10 years.

#### 4.9 Recommended Spare Parts

If any additional spare parts are recommended by the Bidder for a five - year operation period, these shall be specified in the Technical Data Sheets, and the unit price shall be quoted in the Price List for each item.

#### 4.10 Execution

##### 4.10.1 Commissioning Tests

The Contractor shall conduct the following commissioning tests to ensure that the equipment has been correctly installed, all necessary adjustments and settings been made, and that it is in sound condition to operate. The site tests are subdivided in preliminary tests, and operation and performance tests. a) Preliminary Tests

- Complete system pressure testing
- Electrical check of correct wiring and cabling
- Testing and setting of pressure switches, and pressure transmitters
- Measuring of insulation level on electrical plant
- Functional tests of the valves

##### b) Operation and Performance Tests

- Leakage test
- Final adjustment of pressure switches, indication instruments and interlocking devices.
- Compressor performance tests

##### 4.11 Trial Operation

After successful completion of all commissioning tests, the dewatering and drainage shall be subject to a Trial Run. Trial Run Operation shall be carried out under the supervision and responsibility of the Contractor.

#### 5. Air Conditioning and Ventilation Systems

The work to be included under this scope shall comprise of the design, supply all labour, materials, plant, installation and the performance of work necessary for the air conditioning and ventilation works required for the power house not turbine hall, control rooms, etc. The tenderer shall furnish the ISO 9001 or equivalent certificate of the Air Conditioning and Ventilation Systems manufacturer along with its details of certifying agency (accreditation, validity date etc.).

##### 5.1 Air conditioning system



Air conditioning (split type) shall be provided for the control room of the power house. The fresh air shall be provided through the lead to the machine room through ducts and the cooled air distributed to each of the required recipient rooms through the supply ducts and rotated back to the machine room through door grilles and return ducts. The exhaust air is exhausted out of the underground power house with the use of exhaust ventilations fans.

### 5.2 Ventilation system

The ventilation system for the power house shall be of central unit system. The ventilation system shall be so designed to maintain healthy, comfortable indoor environment.

### 5.3 Shop drawings

The contractor shall submit shop drawings showing details of fabrications with adequate calculations for the approval of the Employer. Shop drawings shall show the details of the various parts, and the methods of anchorages, reinforcements, insulations, joints and installation of the works.

### 5.4 Catalogues and samples

Catalogues shall be submitted on all equipment to be provided for the approval of the Employer shall be in English language. Operation and control manuals shall be submitted for the approval of the Employer prior to the installation of the equipment. The data shall also include the manufacturer's installation and servicing instructions and performance details.

### 5.5 Materials and installations

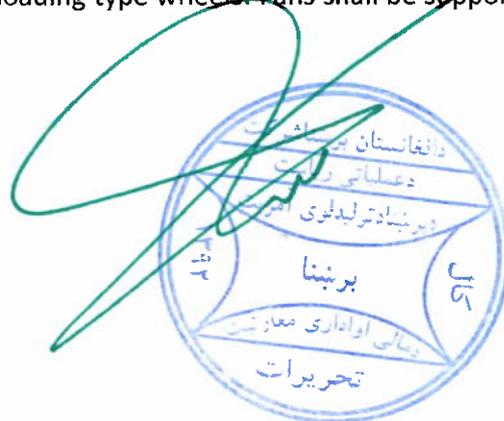
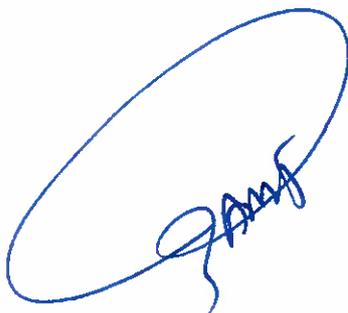
Materials and installation of ventilation air conditioning systems should be well-matched with power plant and must be as per latest design and technology, due to the building structure, changes of sizes or location of ducts are deemed necessary, the following shall apply:

- The changes shall be approved by the Employer
- The hydraulic diameter shall be maintained for the new size ☐ The maximum width to height ratio shall be provided by Employer ☐ The metal thickness shall be based on the new duct size.

### 5.6 Ventilation fans

Fans shall be statically and dynamically balanced and shall be of axial or centrifugal type. Wall mounted fans shall be completed with exhaust hoods fabricated of perfect gauge galvanized steel or spun aluminum with counter flashing as required, electric motor, lockout stop, access arrangement for fan inspection, lubricated bearings, rubber vibration isolators between fan and housing, square opening, bronze mesh bird screen were installed in outside walls and cadmium plated hardware.

Centrifugal fans shall be of the base mounted type with integrally mounted motors, V-belt drive with adjustable pitch and roller bearings with grease connections outside the housing. Fans shall be single suction type with non-over loading type wheels. Fans shall be supported



via spring type vibration mountings as recommended by the manufacturer. Fans shall be connected to ductwork using a flexible neoprene or asbestos connection.

### 5.7 Performance test

Each equipment shall be tested in accordance with applicable code and standards at the manufacture's shop. The Employer shall be given the opportunity to witness all the tests according to approved test plan and all test report certified by contractor whether witness or not.

After all mechanical work covered under this Clause has been completed the air-conditioning and ventilation systems and controls shall be tested for five consecutive eight-hour periods or longer when so directed, to demonstrate that they fulfil all requirements including as stated below.

#### 5.7.1 Air Quality

The air quality inside the powerhouse shall be maintained to provide healthy, comfortable indoor environment in conformity with international standards. The contractor shall supply, install, and test the adequate capacity Electrostatic Precipitator at proper location.

#### 5.7.2 Noise Level

The noise level for the air conditioning unit shall be within the acceptable limit of International Standards for surface power house.

#### 5.7.3 Comfort Condition

- Operative temperature should match the international standard
- Relative Humidity should be as per international standard
- Average air Velocity must be matching the international standard

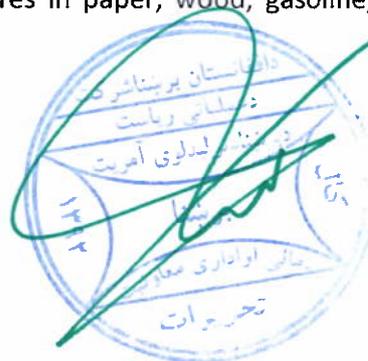
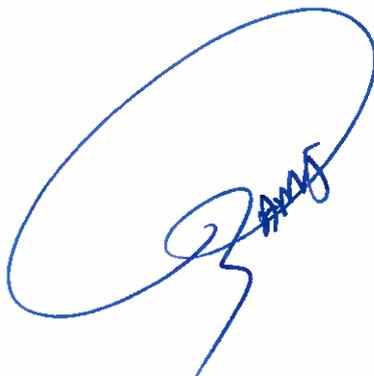
The supply & execution of the works under this section shall be in full conformity as per international standards.

## 6. Fire Fighting System

The work to be included under this scope shall comprises of design, supply all materials & plant for installation and performance test of Power house fire fighting system. The firefighting system shall be equipped with Manual / Automatic water sprinkle firefighting system with sufficient number of automatic alarms, smoke detectors, pumps, strainer and other accessories. The water supply for the firefighting system shall be made available from the powerhouse overhead tank, sump tank and tail race (main water supply system) at all the time.

The tenderer should design, supply & install the necessary piping network for supply and proper drainage for firefighting system and shall be approved by the Employer.

The tenderer shall also supply fire extinguishers of dry chemicals, heavy duty type, portable air pressure operated of adequate capacity as many as required. Each fire extinguisher shall be supplied and filled with a free-flowing moisture repellent and fire extinguishing chemical powder. The chemical powder shall extinguish fires in paper, wood, gasoline, petroleum



products, paints, and gas, chemical and electrical fires. An additional fire extinguishing dry chemicals powder shall be supplied in moisture proof containers for recharging the fire extinguishers.

Suitable chrome finished hooks or hangers with attachment screws shall be supplied and installed as per approved design or as directed by the Employer. The firefighting system shall be tested in accordance with recent international standards or codes.

The Contractor shall be responsible to rectify any problem as per the international standards or codes to satisfaction of the employer. The supply & execution of the works under this section shall be in full conformity with international standards.

#### Chapter 4 – Employer’s Requirements

##### 1. Medium Voltage Switchgear

The works covered by this chapter include the design, manufacture, supply, installation, testing and commissioning at site of the following:

- 1.1 Three (3) No of 10 kV Generator income feeders and 3 three outgoing generators feeders switchgears with all accessories
- 1.2 Two (2) No of 10 kV Station service transformer switchgear with all accessories
- 1.3 Two (2) No of 10 kV for local electrification with all accessories
- 1.4 One 10 kv measurement panel
- 1.5 Spare parts for each

##### 1.2. System Descriptions, Characteristics and Operating Condition

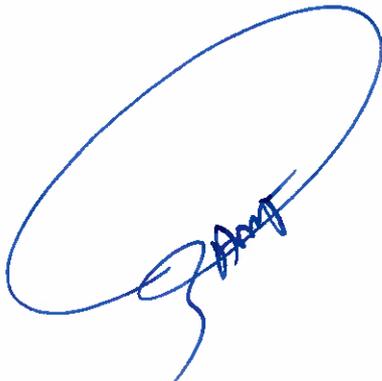
Mahipar Hydropower Plant MHPP consists of three AC synchronous generators each rated at 10 kV, 50 Hz, 26 MVA, and connected to 10/110 kV system income and outgoing switchyard through three numbers of three phase transformer.

Each generator is connected to the 10 kV bus bar through 10 kV switchgear consisting of Oil Circuit Breaker (OCB).

The 10 kV bus bar is connected to the main transformer through an OCB. The generation voltage is stepped up to 110 kV by the three-phase main transformer.

Each Generator synchronizing through 10 kV OCBs. All the generator circuit breakers and auxiliary circuit breakers shall be arranged in one row, accessible from the front side with sufficient space on both side of the switchgear assembly for safe operations. It is required to replace the synchronization system with a modern digital system, to avoid power interruptions and save time while trying to synchronize the generators.

Contractor must carry out design, supply and installation of Computerized control system for entire power plant supervisory automation and control system, All the units and switchyard



shall be controllable via touch Screen from local and from control room. The position of the switchgear shall be as per the location as it is (same as former places):

### 1.2.1 Generator switchgear

There are three generators' switchgears each comprising the followings

- Generator Circuit Breaker
- Cable box for incoming and outgoing XLPE cables
- Current transformers
- One unit of Voltage transformer sets for synchronization for each generating unit.
- One set of Lightning arrester
- Air insulated three phase bus-bar system

### 1.2.2 Station service transformer switchgear

- Two transformer incomer vacuum circuit breakers for each set
- One set of Voltage Transformer connected to the bus bar for each set
- Cable box for incoming and outgoing XLPE cables for each set
- Current transformers
- Air insulated three phase bus-bar system,

### 1.2.3 for local electrification

- transformer circuit breaker
- One set of Voltage Transformer connected to the bus bar
- Cable box for incoming and outgoing XLPE cables
- Current transformers
- One set of Lightning arrester
- Air insulated three phase bus-bar system,

## 2.2. Quality Assurance

### 2.2.1 Reference Standards

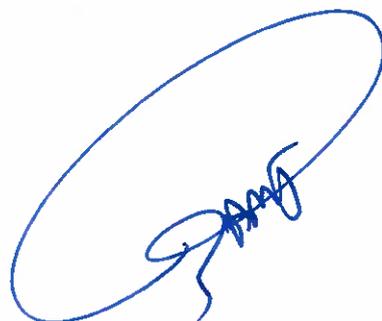
- IEEE Std. C37.013-1993 (Revision of IEEE Std. C37.013-1989): IEEE Standard for AC High –Voltage Generator circuit Breakers Rated on a Symmetrical Current.
- ANSI/IEEE Std. C37.20.2-1987: Metal Clad and Station Type Cubicle switchgear
- IEC 60694-2002: Common Specifications for High-Voltage Switchgear and Control Gear Standards.
- IEC 60298: AC metal-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV.

### 2.2.2 Design Criteria

#### Metal-clad switchgear

Metal-enclosed power switchgear shall have following features.

1. The circuit breaker shall be metal clad; switching and vacuum interrupting type with removable (draw-out) type arranged with a mechanism for removing it physically



between connected and disconnected positions and equipped with self-aligning and self-coupling primary disconnecting devices and disconnectable control wiring connections.

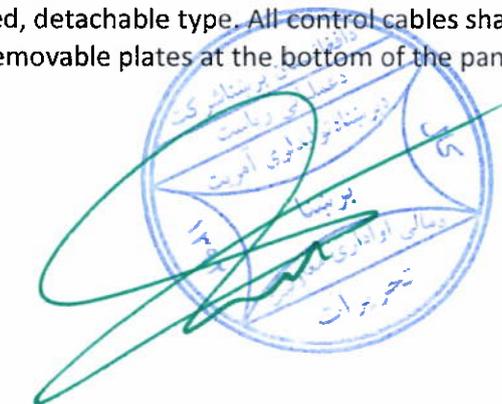
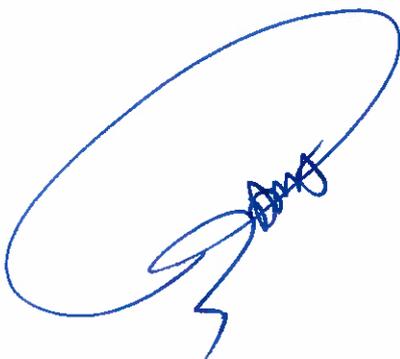
2. Major parts of the primary circuit, that is, the circuit switching or interrupting devices, buses, voltage transformers, shall be completely enclosed by grounded metal barriers that shall have no intentional openings between compartments.
3. All live parts shall be enclosed within grounded metal compartments.
4. Primary bus conductors and connections shall be covered with insulating material throughout. The bus bar shall be extensible type on the sides to enable them to connect with the bus bar of the 10 kV fuse switch.
5. Mechanical interlocks shall be provided for proper operating sequence under normal operating conditions.
6. Instruments, meters, relays, secondary control devices and their wiring are isolated by grounded metal barriers from all primary circuit elements with exception of short lengths of wire as at instrument transformer terminals.
7. Buses and primary connections shall be of copper conductor.
8. Grounding

A ground bus shall be included that will electrically connect together the structure in a switch gear assembly in or on with primary equipment or devices are mounted at all points of connections between the ground bus and the assembly, any nonconductive coating such as paints, shall be removed or penetrated to ensure good electrical contact.

The ground bus for each group of vertical sections shall have facilities for connection to a station ground bus by suitable conductors. Circuit connections to the ground bus shall be made so that it is not necessary to open circuit ground bus to remove any connection made to the ground bus.

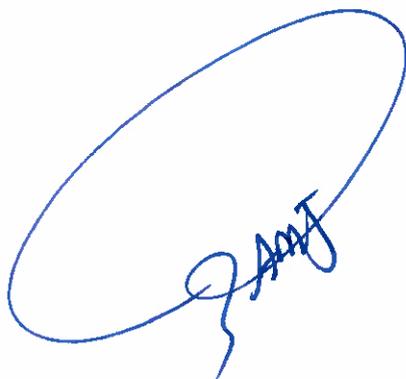
Ground connections shall be provided for all removable elements to ensure that they are all grounded until the primary circuit is disconnected and the removal element is moved to a safe distance.

9. Control and secondary Circuits and Devices All circuits supplied from external/ internal sources (ac or dc) and used for control, relaying or metering shall have short circuit and over current protection. Other circuits supplying loads such as space heaters and lights shall have overload and short-circuit protection.
10. Power Cable pot heads for termination of 10 kV cross linked polyethylene insulated cables shall be furnished. All power cable entry shall be from the bottom and the cable pot heads shall be self-supported, detachable type. All control cables shall enter the switchgear from bottom. Removable plates at the bottom of the panel



shall be furnished with compression type cable glands to make entry dust-tight and no weight is transferred on the terminal.

11. Metal Clad switchgear Barriers: Switchgear shall be provided with metal barriers between primary sections of adjacent vertical sections and between major primary sections of each circuit. Primary sections are: the bus compartment; the primary entrance compartment; the removable element compartment; the voltage transformer(s) compartment; and the control transformer(s) compartment. To minimize the possibility of communicating faults between primary sections, the barriers between primary sections shall have no intentional openings. Barriers are provided to segregate the voltage transformers for each poly phase circuit but not to segregate them individually. Where buses penetrate barriers, suitable bushings or other insulation shall be provided.
12. Shutters On metal-clad switchgear, automatic shutters shall be provided to prevent incidental contact with the live parts of the primary circuit when the removable element is in the test position, disconnected position, or has been removed.
13. Interlocks: Mechanical interlocks shall be provided on metal-clad switchgear as follows:
  - To prevent moving the removable element to or from the connected position when the switching device is in the closed position.
  - To prevent closing the switching device unless the primary disconnecting devices are in full contact or are separated by a safe distance. See ANSI / IEEE C37.100-1981 [test position].
  - Means shall be provided for positively holding the removable element in place in the housing when it is in either the connected or test position. When a separate disconnected position is provided with the door closed, the removable element shall be positively held in this position.
  - To prevent the disconnection of and access to fuses on the primary side of control power transformer unless the secondary circuit is open.
  - Circuit breakers equipped with stored energy mechanisms shall be designed to prevent the release of the stored energy unless the mechanism has been fully charged. Operators and service personnel shall be protected from the effects of accidental discharge of the stored energy by any of the following means:
    - a) Interlocks provided in the housing to prevent the complete withdrawal of the circuit breaker from the housing when stored energy mechanism is charged
    - b) A suitable device provided to prevent the complete withdrawal of the circuit breaker until the closing function is blocked.
    - c) A mechanism is provided to automatically discharge the stored energy before or during the process of withdrawing the circuit breaker from the housing.



14. Interchangeability of Removable Switching and Interrupting Devices All removable elements of the same type and rating on a given assembly shall be physically and electrically interchangeable. Removable elements not of the same type and rating shall not be interchangeable.
15. Control Wiring: Power circuit-breaker control wiring shall be in accordance with ANSI 337.1 Figs 1, 2, 3, or 4.
16. Indoor metal-clad switchgear, Access, and Ventilation Metal-clad switchgear for indoor applications shall be enclosed in general-purpose, ventilated enclosures equipped with front-hinged panels with hand-operated fasteners and bolted rear covers. Ducts or grilles for venting exhaust gases shall be so constructed as to prevent foreign materials from entering the circuit breaker.
17. Position Indication: Indicating lights shall be provided to indicate the open and closed position of the switching devices. Unless otherwise specified, the closed position shall be indicated by a red light and the open position by a green light.
  - charging motor shall be capable of operating for supply voltage variation from -20% to plus 115 % of rated voltages.

### 1.3. Testing

Type test certificates shall include but not be restricted to the following tests.

#### 1.3.1 Type Tests/Certificates:

1. Dielectric strength test (see clause 5.2.1 of ANSI/IEEE C37. 20.2-1987)
2. Low frequency withstands tests (see clause 5.2.1.1 of ANSI/IEEE C37. 20.2-1987)
3. Impulse withstands tests (see clause 5.2.1.2 of ANSI/IEEE C37. 20.2-1987)
4. Rated Continuous Current Test (see clause 5.2.2 of ANSI/IEEE C37. 20.2-1987)
5. Short Time Current Withstand Test (see clause 5.2.3 of ANSI/IEEE C37. 20.2-1987)
6. Mechanical Endurance Test (see clause 5.2.5 of ANSI/IEEE C37. 20.2-1987 and as specified in clause 1.2.3.1 of Generator Circuit Breaker)
7. Rated short –circuit current test. (See Clause 5.2.3.1 of IEEE Std. C37.013-1993)

#### 1.3.2 Routine tests

Routine tests on unit # 1 of all equipment shall be conducted by the manufacturer at the factory as part of the process of producing the circuit breaker.

1. Boards and cubicles. Individual tests according to ANSI/IEEE C37.20.2-1987 standard including interchange ability checks on draw-out appliances;
2. Each appliance shall be subjected to routine test.

Following Routine Tests Shall be carried out on the circuit breaker and the switchgear assembly:

- a) Dielectric Tests (see clause 5.3.1 of ANSI/IEEE C37. 20.2-1987)



- b) Mechanical Tests (see clause 5.3.2 of ANSI/IEEE C37. 20.2-1987)
- c) Grounding of Instrument Transformers case tests (see clause 5.3.3 of ANSI/IEEE C37. 20.2-1987)
- d) Electrical Operation and Control Wiring tests as per ANSI/ IEEE Std. C37.20.2.-1987 clause 5.3.4
- e) Control Wiring Continuity test (see clause 5.3.4.1 of ANSI/IEEE C37. 20.2-1987)
- f) Control Wiring Insulation Test (see clause 5.3.4.2 of ANSI/IEEE C37. 20.2-1987)
- g) Polarity Verification Test (see clause 5.3.4.3. of ANSI/IEEE C37. 20.2-1987)
- h) Clearance and mechanical adjustment check tests (see Clause 5.3.7 of IEEE Std. C37.013-1993)
- i) Mechanical operation tests (see Clause 5.3.8 of IEEE Std. C37.013-1993)
- j) Normal-frequency withstands voltage tests on major insulation components (see Clause 5.3.11 of IEEE Std. C37.013-1993)

### 1.3.3 Site Tests:

Tests at site shall be performed on the generator circuit breaker totally assembled in its final location. Site tests shall include the following, based on the type of circuit breaker. Records of the tests shall be compiled and submitted to the Employer for approval.

- 1. Dielectric tests (see clause 5.5 of ANSI/IEEE C37. 20.2-1987)
- 2. Electrical resistance of current path tests (see Clause 5.4.4 of IEEE Std. C37.013-1993)
- 3. Clearance and mechanical adjustment check tests (see Clause 5.4.5 of IEEE Std. C37.013-1993)
- 4. Timing tests (see Clause 5.4.6 of IEEE Std. C37.013-1993)
- 5. Contact resistance test
- 6. Interlock check
- 7. Operation Tests.

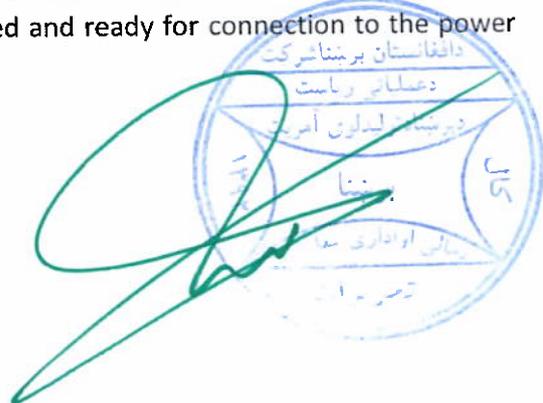
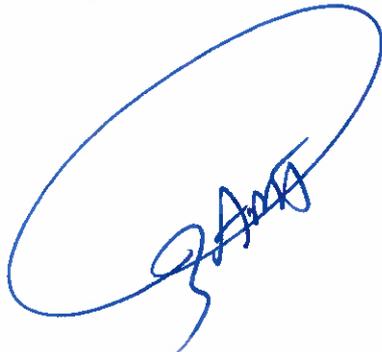
### 1.4. Components-Products and Sub-Assemblies

#### 1.4.1 Fabrication

##### Cubicles

The Medium voltage switchgear and control gear shall be mounted in prefabricated protected metal-clad cubicles for indoor installation and shall be of approved and attractive appearance, adequately dimensioned, and shall consist of rigid, steel-plated cubicles enclosed on all sides and open at the top having full-length doors for easy access to the equipment inside.

All doors shall be equipped with handles and key locks and windows making inspection easy (degree of protection: IP 31). All doors shall be equipped with handles and key locks. Separate compartments shall be provided in each cubicle for the cable inlets. Each cubicle shall be completely assembled in the factory, entirely wired and ready for connection to the power and control cables.



Each carriage control panel including the breaker operating mechanism shall be provided with thermostatically controlled space heater. The thermostat shall have adjustable range of 50C - 120C.

The space heaters shall be rated for 230 volts, 1 phase, 50 Hz. For cubical illumination, receptacle arrangement at suitable location of each control panel shall be provided so that hand lamp connection may be taken from this receptacle during inspection and maintenance. The receptacle shall be suitable for 230 volts, 1 phase, and 50 Hz supply. Wiring for space heaters and panel receptacles shall be suitably grouped so as to form a more or less balanced condition of 400V, 3 phase-4 wire, and 50 Hz supply.

The power for breaker control and indication shall be taken from 220 V DC power supply from the DC distribution board of the substation.

#### **Bus Bars**

Buses and primary connections shall be copper. The bus-bars shall be extensible on both sides. Unused side of the switchgear shall be closed by removable screwed cover sheet. The switchgear buses shall be rated for continuous current. Supporting insulators shall be of the synthetic resin or other approved type. Porcelain insulators will not be accepted.

Maximum temperature rise of bus and connection shall be limited to 50C over an ambient temperature of 45C.

The bus bars of the switchgear section shall be of copper, liberally sized, with high safety factor for required current rating.

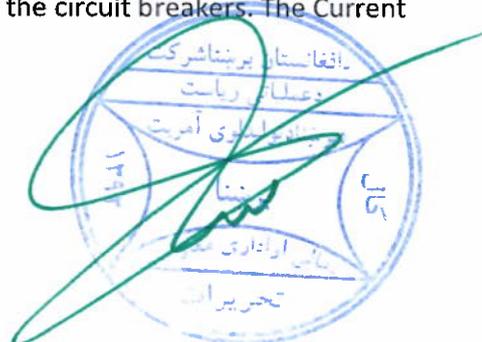
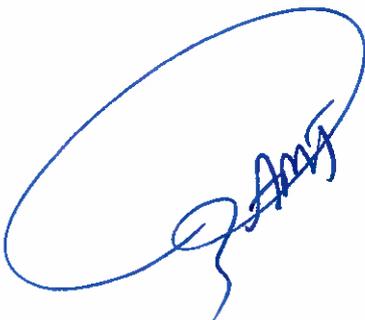
The bus-bar connections and their insulated supports shall be mechanically strong and shall withstand all the stresses which shall be imposed upon them in ordinary working due to fixing, vibration, fluctuation in temperature, short-circuit or other causes.

Provision shall be made for expansion and contraction of the bus-bars and connections with variation of temperature.

#### **Current Transformers**

The selection and application of the current transformer used in this specification shall be in accordance with IEEE Std. C37.110-1996, IEEE Std. C57.13-1993 or applicable equivalent standard IEC 60144 Instrument transformer.

1. The current transformers shall be of epoxy encapsulated/cast in resin type, mounted on stationary portion of the switchgear and shall be easily accessible for maintenance and testing purposes.
2. All secondary connections shall be connected to a terminal block which shall be located in a dust-proof and watertight terminal box and shall be clearly labelled. An earth connection to the housing shall be provided.
3. The core for measuring purposes shall have the ratio, accuracy class and the burden as detailed under the respective specification of the circuit breakers. The Current



transformers will not exceed the ratio error more than 10% at any current from 1-20 times rated secondary current with a standard burden.

4. The burdens of the current transformers for measuring and protection purposes shall be determined according to the technical requirements, but shall not be less than 125% of the overall computed (design) burden of the connected apparatus including cables.
5. Measuring instruments and protective relays shall be separately supplied by different current transformer windings.

#### **Voltage Transformers**

1. The indoor three phase voltage transformers shall be of the single-phase dry synthetic resin type mounted rigidly inside the circuit breaker cubicle and shall comply with the requirements of IEEE Std. C57-13-1993 (ANSI) IEEE standard requirements for Instrument transformers or applicable equivalent standard IEC 60144 Instrument transformer.
2. An earth connection to the housing shall be provided. The windings for measuring purposes shall be designed for accuracy according to class 0.2
3. The voltage transformers shall have an additional secondary winding for earth fault protection, connected in open delta with a resistive burden. The accuracy class shall be 3P.
4. The high voltage winding of the potential transformer shall be protected by current limiting fuses and the secondary shall be provided with miniature circuit breakers with alarm contacts. The primary fuses of voltage transformers shall be mounted in such a way they must be disconnected from the primary circuit before access can be obtained.
5. The burdens of all windings shall not be less than 125% of the overall computed (design) burden of the connected apparatus including cables.

#### **1.5. Accessories and Submittals**

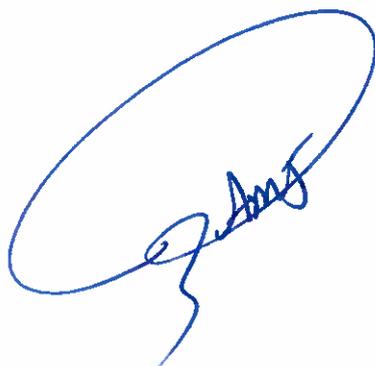
Following accessories shall be provided for each switchgear:

1. Channel base and foundation bolts
2. Lifter
3. Maintenance closing handles for circuit breaker
4. Draw handle for circuit breaker
5. Test plug for draw out type relay.

#### **1.6. Drawing S, Data and Manual**

The following drawings and details shall be submitted:

- Space required in the front for breaker withdrawal.
- Power cable, Control cable entry points and termination arrangement.
- Bus bar clearance phase to phase and phase to ground.
- Control panel details with equipment layout.



- Terminal blocks details.
- Single- and three-line diagrams of all switchgears showing instrument transformers, control switches, instruments and indication, etc.
- Control schematic diagram of each breaker showing all safety and operation interlocks, annunciation, etc.
- Transport/shipping dimensions with weights.
- Foundation and anchor bolt details including dead load and impact load.

#### 1.7. Spare Parts

Bidder shall provide at least 10% spare part from axillary parts list relays, measurement and protection devices.

#### 1.8. Execution

##### 1.8.1 Site Tests

The site tests shall be carried out in accordance with the approved QC plan and related Standards. As a minimum requirement the following tests shall be performed at site.

##### 1.8.2 Bus-Duct System

- Visual inspection;
- Measurement of insulation resistance;
- Bus bar tightness test and test of pressurizing system;
- Resistance measurement of conductors at ambient and service temperature;
- Check of the bolted joints by means of “thermo-paper or paint”, or other approved method; the test shall be carried during load tests of the generating unit.

##### 1.8.3 Generator Voltage Switchgear

- Visual inspection;
- Measurement of insulation resistance;
- Function and operation tests of all switching devices;
- Testing of control, protection, measuring and interlocking circuits.
- Primary injection test;
- PT ratio
- CT ratio
- All other importance test like interlock operation etc

#### Chapter 4 – Employer’s Requirements

##### 1. Automation and Control Systems

The control systems of Mahipar hydropower plant MHPP is 24 and 220 VDC systems, all control systems operation is conducted manually in case of operation the operator is



obligated to go downward (underground floor) for operation. The system is not working properly sometime system is being in malfunctioning. The exist control systems and control room with panels must be changed to the latest and modernized systems as per new technology and international systems, and the power plant shall be provided with a state of the art modern and latest technology equipped control system and control room, comprising One (1) Power Plant Automation and Control System (ACS).

The scope of work shall include all required studies, calculations, design as per international standard, engineering, manufacturing, supply, submission of drawings and documents, shop and site testing, erection, adaptation to related equipment, commissioning and training services for the ACS and its components.

The ACS shall be fully developed, debugged, commissioned and tested for manual and fully automatic control of the power plant.

The ACS shall principally be composed of the following systems, components and ancillaries not being limited to:

### 1.1 Central Control Room Equipment (CCR)

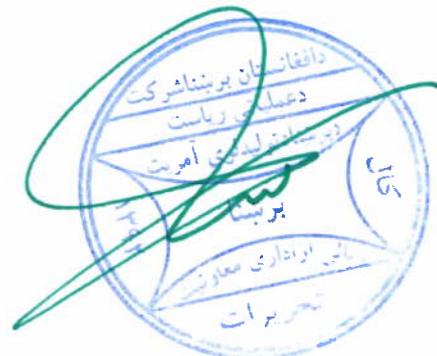
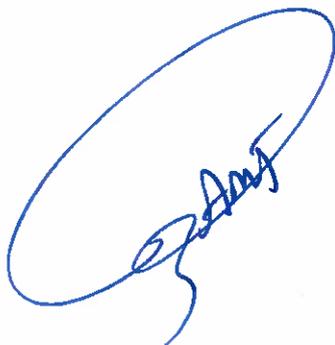
- Two (2) operator stations with monitors and alarm printers;
- One (1) redundant 10 / 110 kV LCU;
- One (1) redundant common services LCU;
- One (1) training and simulation station with double monitor and printer;
- One (1) engineering station with double-monitor and laser color printer;
- One (1) redundant main server in hot-standby;
- One (1) interface with firewall to Office LAN and Web Client for remote access;
- One (1) GPS master clock system with interface to secondary system;
- One (1) redundant gateway to the Load Dispatch Centre (LDC);
- One (1) portable service station;
- One (1) redundant fiber optic bus system according to IEC 60870-5-104;
- One (1) lot of RTU
- One (1) set of furniture for the CCR.

### 1.2 Unit and Peripheral Controllers (LCU)

- One (1) operator station with monitors and alarm printers for the local and PH control room;
- Two (2) redundant unit controllers (LCU) with field-bus interfaces to sub-controllers and monitors;
- One (1) redundant station auxiliary LCU;

### 1.3 Headwork Control Room Equipment (HCR)

- One (1) operator station with monitors and alarm printer;
- One (1) redundant LCU with field-bus interfaces to sub-controllers, LCC and monitors;
- One (1) set of furniture for the HCR.



The ACS shall include all additionally necessary instruments, sensors, adapters, transmitters, wires, cabling, Ethernet repeater stations, and data bus systems as a fully functioning system complete in every respect. All necessary control processors, input / output (I/O) cards, redundant power supplies, data interfaces, marshalling and termination facilities shall be provided. The electronic hardware and associated components shall include the capacity for an overall 30% extension capacity.

## 2. System Concept

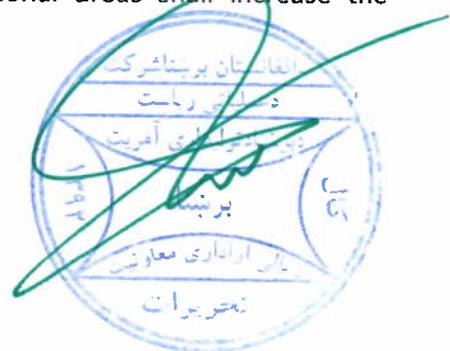
The ACS shall be characterized by an innovative system concept, powerful communication capabilities and a scheme-wide unique engineering and configuration tool. The ACS shall consist of state-of-the art equipment and components, applying the latest knowledge and achievements in the industrial process automation technology, such as:

- Client-Server / Master-Slave concepts;
- Object-oriented processing of data;
- Re-usable automation software objects and program modules;
- High-level of hardware modularity and scalability;
- System-wide data management and data access with single data entry;
- Central engineering system to program and configure all system components;
- Long-term availability of components;
- Expandability;
- Standard-based communication from field to management level;
- Standardized 10/100/1000 BASE FX Gigabit-Ethernet bus system;
- Application of IEC 60870-5-104 protocol;
- Distributed redundant concept;
- Integrated alarming;
- Time correct processing;
- Effective human-machine interfaces;
- Window-based operation system, process diagrams and sequential controls; □ Total plant efficiency optimization modules and diagnosis functions.

Expansion or software updates of the ACS shall be enabled based on an open system architecture concept and by strictly applying international communication standards for the main-, process- and field-bus applications.

## 3. System Architecture

The ACS shall be designed in consistent hierarchical and decentralized structure. Dividing the total scheme automation system into autonomous functional areas shall increase the



availability and guarantee all time pre-defined and safe operating modes in case of emergency situations.

The ACS shall be designed to ensure maximum availability by the inclusion of built-in redundancy for both hardware and software. This shall include duplicated control processors, bus systems and power supplies with automatic change-over to the standby device upon detection of a fault or failure. Where appropriate, I/O cards shall also be duplicated.

Easy and safe operation of the power plant and its components shall be enabled by installing touch panels as human-machine interfaces (HMI) at the unit control boards (UCB) and ergonomically designed graphical user interfaces.

The system shall be designed for industrial use and withstand permanently the climatic and electro-magnetic environmental conditions in a power plant (EMC and ESD).

The ACS shall contain self-monitoring hard- and software functions. Software self-supervisory and fault diagnosis functions and plausibility checks shall lead to an early detection of abnormalities and therefore to a high availability of the plant. Comprehensive system diagnostic facilities shall be incorporated also to assist in maintenance and troubleshooting. A failure of any single element shall not affect the operation of any main system of the power plant in operation. In particular, the duplicated controllers shall enable a failure tolerance in order not to affect the plant operation or any control sequences. All process signals shall be managed without multiple engineering (single data-entry). The three operator stations with three monitors, keyboards, printers and peripheral devices and their associated control desks shall allow monitoring, control and adjustment of all relevant plant operation tasks via high resolution window-based graphic displays.

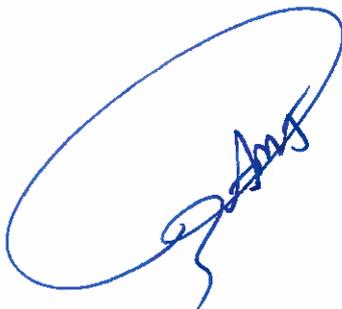
The main bus system shall be arranged as a dual fiber optic ring network and realize the data transfer between the redundant main servers, the control room HMI equipment, and all other related controllers according to the system architecture drawing.

The process bus system shall also be arranged as a dual fiber optic ring network and realize the data transfer between the redundant main servers, the unit controllers, and all other related controllers according to the system architecture drawing. Both bus systems shall apply IEC 60870-5-104 as protocol standard. Sub-systems as the MIV LCC, digital turbine governor, static excitation system, generator circuit breaker and digital protection systems shall be interlinked by standard field bus systems, arranged in redundant star shape. The ACS shall be connected to a standard master clock system to guarantee synchronization of all ACS components.

The UCB shall be equipped with instruments for indicating the following:

- Active and reactive power, stator voltage and current, field voltage and current;
- Turbine discharge, unit speed, MIV position, pressure u/s and d/s of MIV; ➤ Wicket gate in operation and limiter position.

For position indications of the circuit breakers and disconnecting switches, a mimic diagram shall be provided on the unit control board. The signals to the position indicators shall be supplied from interposing relays.



#### 4. System Main Features

The ACS shall be designed to ensure maximum plant availability and efficiency. In its final configuration, the ACS shall be capable of controlling and monitoring the operation of the entire power scheme, the turbine-generating unit, individual sub-systems and auxiliary equipment.

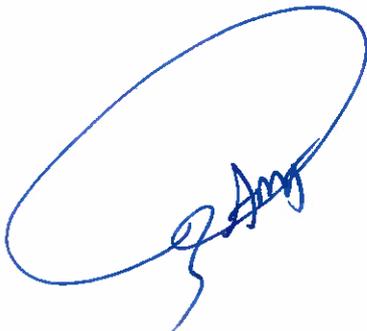
Open system standards and international software protocols shall facilitate interconnectivity to a wide range of optimization and diagnosis applications as well as asset management systems. A high level of modularity and system scalability shall allow optimum process adaptation. The use of standard industrial components shall assure long-term availability and reduce spare part costs.

The following installations and equipment shall be monitored and controlled by the ACS:

- Headwork's consisting of intake block, dam, diversion dam, settling basin, forebay and power intake with related gates, control, monitoring and measuring equipment;
- Turbine including MIV and turbine outlet gate, governor and ancillary equipment;
- Synchronous generator, excitation systems and ancillary equipment;
- Generator main circuits with generator circuit breakers;
- Main transformers;
- Station auxiliary supply systems (MV switchgear, station service and auxiliary transformers, LV switchgear, DC / UPS systems, diesel generating units);
- Common services (cooling water system, drainage and dewatering system, HVAC systems, compressed air system, fire protection system, potable water system, and sewage treatment plant);
- Tailrace outlet gate;

The ACS shall cover the following functions:

- Fully automatic control and monitoring to provide safe start-up, synchronizing, loading, shut down and emergency tripping of unit 1;
- Provision of active and reactive power joint control / joint discharge control;
- Transmission line charging;
- Plant operation forecast schedule module (daily / 7 days);
- Plant optimization software module (operation of active units in maximum efficiency point);
- Total discharge calculation module (including dam radial and all other gates);
- Data acquisition from the main transformers and Switchyard;
- Control and monitoring of the dam gates, intake gates and tailrace outlet gates;
- Facilities for comprehensive monitoring, storage and presentation of information concerning plant conditions, performance and historical archive;



- Energy metering of scheme output and provision of data for invoice purposes;
- Standard master clock systems;
- Life-beat monitoring;
- Provision for black start capability; ➤ Interface with the LDC.

## 5. Control Hierarchy

The ACS shall be suitable for the operation at the following control levels:

### 5.1 Load Dispatch Centre (LDC)

The commands shall operate the active and reactive joint control / joint discharge control set-points of the plant. Start / stop of individual unit 1 which are set to automatic LDC control in the CCR shall be enabled.

### 5.2 Central Control Room (CCR)

The highest control level in the power station shall be designed for automatic control and monitoring of the entire power plant unit # 1. Comprehensive monitoring of the headwork's, the generating unit # 1, MT, station auxiliary equipment and station services shall be provided. The functions in this mode shall basically be the same as those for the automatic operation mode at UCB level. For general overviews of the plant situation, a large screen system shall be provided.

### 5.6 Unit Control Board (UCB) and Local Control Units (LCU)

From the UCB it shall be possible to operate the units manually and automatically. The control modes shall be selected with three positions key selector switches installed in the front panel or with switches integrated in the HMI.

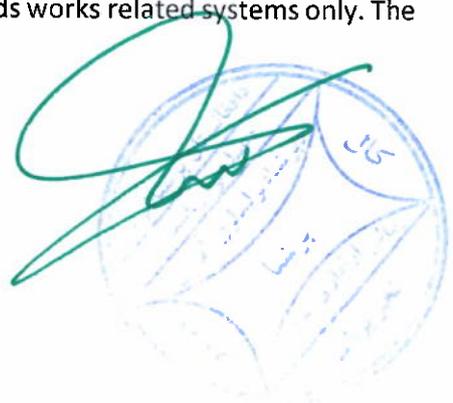
- In LOCAL-MANUAL mode the automatic sequences shall be executed stepwise with all relevant monitoring and safety functions active. The control priority is at the UCB.
- In LOCAL-AUTOMATIC mode all automatic sequences and functions shall be active. The control priority is at the UCB.
- In REMOTE-AUTOMATIC mode the control shall be transferred to the CCR and the LDC respectively

### 5.7 Local Control Cubicles (LCC)

On the lowest level of the control hierarchy, local control cubicles shall enable the operation of individual equipment or sub-systems. These control facilities shall be mainly used for testing and maintenance purposes. As a back-up of the normal operation or during maintenance activities, it shall be possible to operate functional groups of the power plant, either in automatic or manual mode.

### 5.8 Headwork's Control Room (HCR)

The HCR is intended for controlling and monitoring the heads works related systems only. The control priority can either be at the CCR or at the HCR.



## 6. Control Modes

The digital turbine governor shall provide the following control modes:

- Speed control, for no-load, isolated- and interconnected-grid operation (PID-P);
- Power-frequency control (PI);
- Discharge-frequency control (PI);
- Water-level control (PI);

In speed control mode, three sets of PID parameters shall be provided: one set for no-load, one for isolated-grid and one for interconnected-grid operation. The parameter sets shall be tested and optimized to provide stable control behavior in case of abrupt changes in the network configuration.

In power-frequency and discharge-frequency control mode, an adjustable linear network frequency stabilization function (power-frequency, respectively power-discharge droop) shall be implemented.

### 6. Line Charging Sequence:

All required hardware, interfaces and software to enable automatic charging of 110 kV transmission lines shall be provided. The control features shall be coordinated with the related equipment such as governor, excitation system, HV installations and the network requirements.

The automatic control sequences shall strictly follow the requirements of the network study and national load control center NLCC.

## 7. System Interfaces

### 7.1 Load Dispatch Centre (LDC)

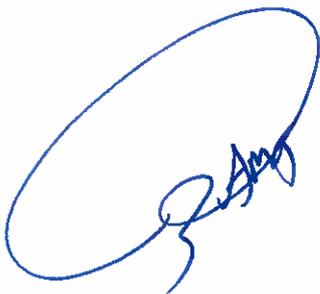
Two redundant communications links to the LDC shall be provided. The ACS shall be linked to the telecommunication system of Afghanistan electricity authority in order to transmit process data to the NLCC.

The data transfer between the gateway computers of the ACS and the redundant routers shall be implemented via an optical or electrical Gigabit Ethernet link (1000 Base LX / 1000Base T). The telecontrol protocol according to IEC 60870-5-104 shall be used for data exchange with the LDC. The corresponding protocol conversion to the control systems internal telecontrol protocol (e.g. DNP 3, Modbus, etc.) shall be the Contractor's responsibility. The pertaining Afghanistan electricity authority specifications for the power system / dispatch system interface shall be observed. The final data exchange requirements shall be determined during the detailed design.

The following commands, status indications, alarms and measuring values shall be provided, but not be limited to:

#### Commands and status indications

- Start / stop of joint control / individual unit;



- Set point joint control / individual unit;
- Indication joint control ON / OFF;
- Indication for unit status;
- 110 kV Switchyard circuit breakers and disconnecting switches; □ AC/DC station auxiliary supply systems and common services. **Alarms**
- Generating unit auxiliary system alarm;
- Generating unit protection operation;
- Generating unit turbine protection operation;
- Generating unit turbine operation warning; □ Generating unit over-speed warning; □ Protection status.

#### Measuring values

- Gross and net active power [MW] and reactive power [MVA] of each unit and plant total;
- Gross MWh produced by each unit and plant total; □ MW and MVA<sub>r</sub> values of the station service transformers; □ Headwater and tailwater levels.

The signal exchange with the LDC shall be in accordance with the Afghanistan electricity authority standard signal list.

#### 7.2 Headwork

The local control cubicles (LCC) provided with the hydro-mechanical equipment shall be connected to the LCU installed in the HCR by bus connections with appropriate interfaces to realize the data transfer between the headwork's equipment and the ACS.

If required, the data transfer between the ACS and the LCC of the gates shall be processed via protocol converters. The interfaces shall be coordinated accordingly. The hydro-mechanical equipment shall provide LCC at the following locations:

- Dam LCC for intake gates, spill way gat, dam diversion
- Settling basin LCC (if requires)

The following information shall be confirmed with hydro mechanical works as a minimum:

- Trash rack losses;
- Level measurements;
- Gate control and position indication; □ Individual and group alarms.

#### 8. Design Requirements

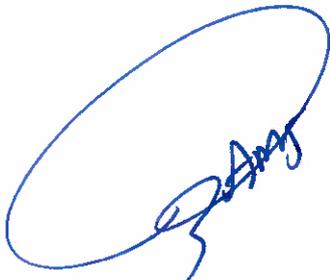
##### 8.1 Applicable International Standards

Unless otherwise stated hereafter, ratings, characteristics, tests etc. of the control equipment shall comply with the provisions and requirements of the latest issues of the following IEC publications as applicable:

IEC 60051 Direct acting indicating analogue measuring instruments and accessories;

IEC 60255 Electrical relays;

IEC 60439 Low voltage switchgear and control gear assemblies;



IEC 60473 Dimensions for panel mounted indicating and recording measuring instruments;  
IEC 60521 Class 0.5, 1 and 2 alternating-current watt-hour meters;  
IEC 60687 AC static watt-hour meters for active energy (classes 0.2 S and 0.5 S);  
IEC 60688 Electrical measuring transducers for converting AC electrical quantities;  
IEC 60751 Industrial platinum resistance thermometer sensors;  
IEC 60801 EMC for industrial-process measurement and control equipment;  
IEC 60870 Tele-control equipment and systems;  
IEC 60947 Low voltage switchgear and control gear;  
IEC 61000 Electromagnetic compatibility (EMC);  
IEC 61082 Preparing documents used in electro-technology, Part 1; Part 2, Part 3;  
IEC 61131 Programmable controllers;  
IEC 61158 Field-bus standard for use in industrial control systems;  
IEC 60617 Graphical symbols for diagrams;  
IEC 60625 Programmable measuring instruments – Interface system;  
IEC 60381 Analogue signals for process control systems;  
IEC 60044-1 Instrument transformers;  
IEC 60186 Voltage transformer; IEC  
8802 Information technology.

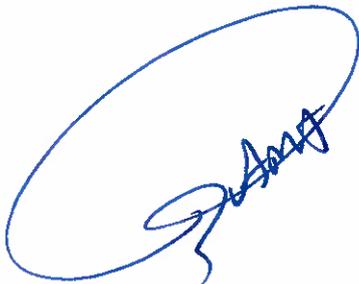
The following international standards shall be applied for the automation and control systems:

- ✓ IEEE 802.3 (Ethernet) network access layer;
- ✓ OPC (Object Linking and Embedding for Process Control).

## 8.2 System Software

The latest version of the manufacturer's systems software packages shall be provided fully developed and tested. All software licenses necessary for the plant operation and maintenance shall be included. This shall lead to unrestricted use of all operator-level applications required for the safe and reliable operation of the plant and its components. Access to software and application programs at various levels shall be possible by operating or engineering personnel using passwords. This shall protect the software from unauthorized access.

The software and associated displays, reports, databases, etc. shall be fully debugged in the shop before testing and commissioning at site. The modification of displays, reports, databases or control strategies shall be possible on-line by the engineering personnel without affecting the plant operation. Modifications to the software shall be done in straightforward and logical steps using, wherever possible, graphic displays. The HMI software applications shall enable the operator to carry out the necessary actions in a safe and efficient manner.



Where process measurement data need to be measured redundantly, the values shall be averaged in the ACS before being processed in control algorithms. For analysis or maintenance purposes the operator shall have the possibility to access either the original values or the averaged value.

#### 8.4 Control and Supervisory Functions

The control and supervisory functions shall include but not be limited to:

- Mode transition of the unit 1: The mode transition shall be fully automatic; any two-mode combination between stand-still, black start, generator and synchronous condenser operation shall be possible. The automatic switching of circuit breakers and the operation of the station auxiliary and common services equipment shall be included.
- Realizing active power or discharge control with frequency influence of unit # 1 or of the entire power plant in joint control.
- Realizing reactive power regulation or voltage regulation either of unit # 1 or of the entire power plant in joint control.
- Operation of circuit breakers, isolators, earthing switches, electric braking switches.
- Starting / shut down or raising / lowering operation of unit auxiliary equipment or power plant common equipment, etc.
- On / off of threshold overshoot alarm measuring points: It shall be possible to modify different threshold values on the engineer station. The alarm signals and fault anomaly views shall be re-settable either manually or automatically.

The emergency shutdown commands generated by mechanical or electrical protection devices shall have the highest priority in all operation modes. The ACS shall have necessary hardware and software measures to ensure permanently the invalidation of erratic commands.

#### 9. Total Plant Efficiency Optimization Modules and Diagnosis Functions

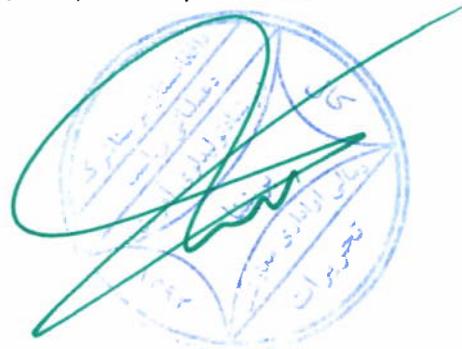
##### 9.1 Diagnosis:

The following diagnosis modules shall be provided:

- Vibration monitoring;
- Air Gap monitoring;
- Partial discharge monitoring;
- Cooling & winding temperature diagnosis;

##### 9.2 Controller for Active Power / Discharge and Reactive Power Joint Control

Depending on the load situation, the network requirements and the reservoir status, the joint control algorithm shall be selectable as Active Power or Discharge Control. Independently Reactive Power Joint Control shall be available in both modes. In order to participate in grid frequency stabilization, in both joint control modes, i.e. active power or discharge joint control, the speed droop function (power / discharge frequency control) shall be active.



In the event of unit load rejection(s), the respective power / discharge set-point values shall be fed forward to the remaining unit for immediate take-over and quick re-stabilization. The control algorithm shall automatically compensate load / discharge variations of unit # 1.

The joint control algorithm set-points, limit values and internal parameters shall be adjusted to achieve the optimum in economical operation of the entire power scheme taking into account the grid situation, the water resources and the number of units out of operation or with restricted generation performance.

The reactive power joint controller shall calculate the required reactive power value, distribute and adjust the values proportionally to the unit # 1, taking into account the network situation and the unit active power output.

The start / stop order of the unit # 1 participating in joint control shall be according to operating hours and actual water resources. The joint control software shall minimize water losses due to frequent start / stop operation.

The joint controller shall receive the power plant set-points continuously from the LDC or either by predefined daily or weekly schedules.

### 9.3 Total Discharge Calculation Module

The total discharge calculation software module shall perform calculations on the power scheme's total discharge (turbine-generating unit, dam radial and other gates).

The discharge values shall be periodically calculated for each gate, considering the gate operation mode, the actual gate position and head conditions with the use of head dependent opening / discharge curves to be provided by the hydro-mechanical equipment supplier.

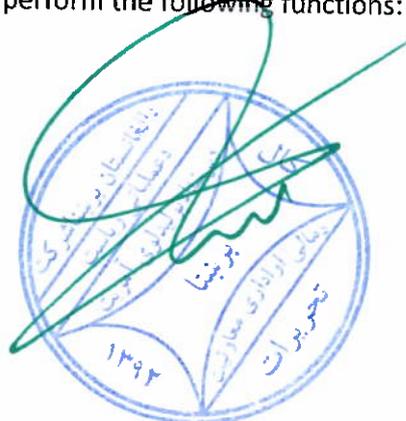
### 9.4 Economic Operation Module

In order to minimize the production and maintenance costs, an economic operation module shall be supplied.

With the economic operation module, it shall be possible to improve the maintenance strategy and to integrate and synchronize information from disparate systems in a global interface to support the operation of the scheme.

The reservoir operation, the energy production, and the production scheduling shall be optimized.

The system shall assist in power scheduling and keeping the generating unit within the required operational limits. For diagnosis and analysis of the individual equipment availability, a status database shall be generated. The accumulated operation time and continuous outage times of the equipment / components shall be considered carefully. Authority and environmental regulations such as up- or downstream water flow limitation, filling and discharging gradients, level limitations shall be considered. Operational forecasts shall be based on meteorological data (precipitation, temperatures) and the calculation of incoming water quantities. The economic operation module shall perform the following functions:



- Determination of the optimum of unit # 1 to operate at present water head according to the assigned load schedule;
- Determination of the unit starting priority according to the actual status of each unit. In particular, the foreseen load condition shall be contemplated when starting / shut down a unit, in view of avoiding unreasonable starting / shut down.
- Sharing power output among the operating unit # 1 to achieve an optimum total efficiency. The power sharing among units shall be based upon the principle that the total water consumption shall be minimal.
- Check of safety constraints, e.g., reservoir levels, cavitation zones and vibration limits of the turbine and generator.

There shall be different schemes of economic operation provided for operator's choice as follows:

- Closed loop regulating scheme: The ACS executes directly the starting or shut down sequence of unit # 1 and the regulating of power according to the results of computation;
- Open loop regulating scheme: All computation results shall be displayed on the displays, but the execution may only be carried out after confirmation by the operator;
- Semi-open loop regulating scheme: commands for power regulating may be executed by the closed loop regulating scheme, but the starting / shut down commands shall be executed only after confirmation by the operator;
- All starting / shut down commands and power regulating commands under these regulating schemes shall be recorded by the ACS;
- The economic operation program shall be initiated periodically; the time period shall be adjustable;
- The daily active power load curve or the real time objective load value of the power station shall be assigned either from remote or by the operator in the control room. The switchover of the control level shall be carried out on the operator station in the CCR, no disturbance shall occur during switch-over.

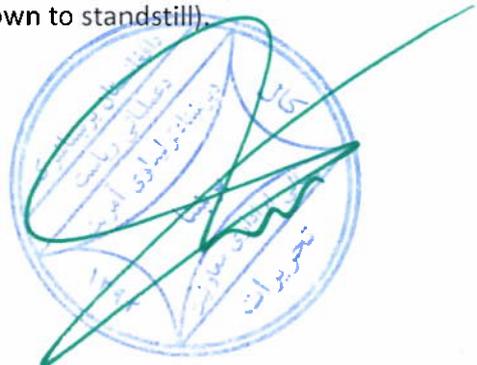
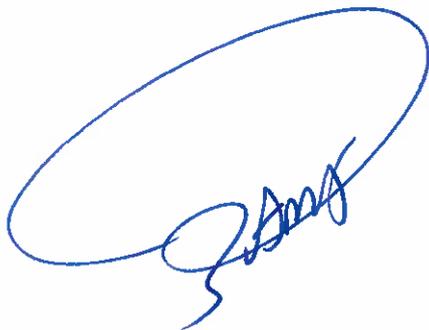
## 10. Sequential Control Functions

### 10.1 Control and Supervisory Functions

Completely automatic start-up and shut down with supervision of control sequences including all transfers and emergency shutdown sequences shall be provided. Special attention shall be paid to the unit control with regard to load rejection, the surge shaft levels and load pick-up. The control features shall be carefully coordinated with the requirements of the hydraulic system and the national grid.

### 10.2 Quick Shut down

All signals which initiate quick shut down of the unit shall be collected by a relay identified as 'mechanical failure trip relay' (fast closure of wicket gate correlated with unloading, close to no-load open signal to the main circuit breakers, shut down to standstill).



In parallel to the hard-wired trip relay, the shutdown command shall be transferred via the communication bus system.

### 10.3 Emergency Shut down

All signals which initiate emergency shutdown of the unit shall be collected by a relay identified as 'electrical failure trip relay' (immediate tripping of main circuit breaker depending on the failure type, unit speed shall be stabilized at 100 % or the unit shall shut down to standstill.

In parallel to the hard-wired trip relay, the shutdown command shall be transferred via the communication bus system.

### 10.4 Synchronization:

#### 10.4.1 Automatic

- Each UCB shall be equipped with an automatic synchronizing device. The automatic synchronizing devices shall work on a fully automatic basis, i.e., once the synchronizing command has been issued the turbine speed and generator voltage shall be automatically adjusted to the correct value and the generator circuit breaker closed at the right moment.
- The equipment shall be of dual channel, self-monitoring type provided with angle measuring transducers, voltage matcher and frequency matcher unit, as well as with a command generating unit. At least setting of two different breaker closing times shall be possible.
- The devices shall be provided with testing facilities to check both channels individually. Manual and automatic testing shall be possible for periodic checking of set values and functions.
- The adjustments shall feature the following: ✓ Sampling frequency;  
✓ Speed and voltage differential values;  
✓ Breaker making time;  
✓ Vector angle mismatch; ✓ Overall operation time. □ In automatic synchronization mode, the measuring instruments and synchro-check relay as described for the manual operation shall be in service.
- With the selector switch in TEST position all automatic functions shall be executed without the breaker closing control. The successful breaker closing shall be indicated by LED.

#### 10.4.2 Manual



Unit 1 shall be provided with one set of independent manuals synchronizing equipment installed in the UCB.

For manual synchronization the following instruments shall be provided at each UCB:

- One (1) double voltmeter;
- One (1) double frequency meter;  One (1) synchro scope.

By means of a key operated selector switch MANUAL / TEST / OFF / AUTO put to the MANUAL position, the reference voltages shall be connected to enable manual adjustment of turbine speed and generator voltage.

Manual closing of the generator circuit breaker shall be monitored by a synchro-check relay to prevent mal-operation. This relay shall compare phase angle, voltage difference and frequency difference with pre-set values.

The relay shall also feature the following operation modes:

- Synchronizing check;
- Dead line / live bus check and vice versa;  By-pass (check function inoperative).
- Dead line –dead bus
- Dead line – live bus
- Live line –live bus
- Live line –live bus

**The synchronization should be possible in 10 kv bus and 110 kv bus**

## 11. System Configuration

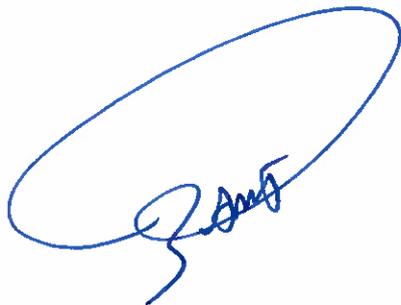
### 11.1 Operator Stations with Relational Database

Three operator stations, each fitted with three monitors and printers shall be provided for the complete operation and supervisory functions.

The main machine interface shall incorporate the following functions:

- Monitoring and operation of the entire power scheme;
- Event handling and event list;
- Alarm functions and alarm list;
- Trend data logs and trend display;
- Report functions;
- Status list;
- Display printout;
- Communication with controllers;  Display design and integration.

A relational database shall be used in the operator stations whereby the standards ODBC (Open Data Base Connectivity) and SQL (Structured Query Language) shall be used. The integral OPC server (Object Linking and Embedding for Process Control) shall make available



all process data to other office applications. The operator station shall also receive data from other OPC servers. OPC shall permit simple, standardized access to process data.

### 11.2 Large Screen with Controller

A high-resolution large screen shall be installed in the CCR. The relevant displays shall be selectable from the large screen controller.

The large screen shall include the interfaces to the ACS and shall include all related supports and equipment, coupling units, software etc. to provide a functional system. The large screen shall be operable in parallel to the monitors.

### 11.3 Fire Alarm Panel

The secondary fire alarm panel (FAP) shall be an integral part of the firefighting system. The FAP shall be considered in the CCR layout and installed under this Contract. The FAP shall be linked to the central fire protection system via the main bus in order to display alarm messages also on the operator stations.

### 11.4 Metering Station

The metering system shall be of digital type with accuracy classes suitable for revenue purposes.

The pertaining national specifications for power system / dispatch system interface shall be observed. The gateway protocol shall be in accordance with the national protocol standards. The metering station shall be capable of receiving energy pulses from the active and reactive energy transducers or the contact signals and capable of counting and saving them, transmitting them periodically or according to the scanning requirement. The pulse counting rate shall be not higher than 10 pulses / s and the register capacity shall be equal or greater than 16 digits of binary code. The accumulated pulses shall be converted with a conversion factor and displayed with the actual kWh and kVarh.

### 11.5 Archiving Station for Long Term and Spontaneous Data Archiving

Sudden and long-term archive functions shall be implemented. The data storage can either be event related or periodic. Logic and analogue variables shall be sampled at 5 s intervals. Event related: logic variable state changes, threshold and limit violations, commands, active and reactive power settings.

The spontaneous archive shall allow very fast archiving. After a change of any object configured for archiving, the software shall store the current value into a buffer for transfer to the spontaneous archive. The archiving server shall also be used for long-term storage of data (process values and messages) of the ACS.

The archiving server shall be capable of presenting pre-defined reports to the operator. The information on the reports may be either in tabular form or in a pre-formatted report form and may be automatic at specific times or on request. Reports shall include periodic logs, daily logs and group logs for the plant and logs of hydraulic conditions. All report formats and the



quantity of available different logs shall be subject to approval by the Employer. Peripheral devices for the storage / recording of plant data shall be provided. These storage devices shall be based on high-capacity magnetic media with facilities to copy their contents to and from an exchangeable medium. The archiving server shall incorporate long term data logging facilities for all analogue, digital, serial data and other internally generated points including the overall extension capacity specified. All signals shall either be scanned periodically or reported by exception, and updated values or digital status changes shall be stored. Data shall be stored for up to 3 months on a suitable storage medium. An alarm shall be created when the storage medium approaches its maximum capacity. All data shall be automatically archived and retained for future reference in either optical or magnetic medium.

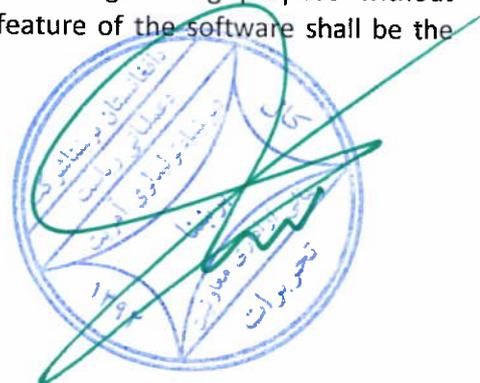
The operator shall have the facility to present real time data, recall data held in the data logger memory or from archives over a specified period of time. The requested information shall be presented on the operator stations either in tabular form or as selected variables on a trend display. It shall be possible to compare on the same display, multiple trends of Realtime data or historical data from the data logger or archives.

All operation events, all events of alarming and all tables shall be displayed on the monitors, printed out and stored on DVD. The printed logs shall be divided into several kinds, such as periodic logs, fault and abnormality logs, operation logs and logs on request. The most notable contents shall be:

- Operation log: record each and every operation in the power plant automatically in the sequence of occurrence, including the equipment operated, operating instruction, operating time, process of execution, result of execution and the time of operation completion.
- Alarm event log: record automatically each alarm / event in time sequence, including the time at which the event occurred, contents and items, create a summary table for alarms and separate for events.
- Tables: create various hourly, daily and monthly statistic tables, also create any kind of tables as directed by the operator.
- Trend log: record the tendency of changes of important supervised quantities.
- Plotting trends, actual load curves, etc. by printer or plotter. The Contractor shall prepare contents and forms of the logs based on the requirement of the power plant.

#### 11.6 Training and Simulation Station

The training and simulation system shall be used to train the operators, engineering and maintenance personnel of the power plant. The training and simulation station shall consist of operator-, server- and archive-functionality, including an interface to a separate LCU system, which shall be used flexibly for each process type. The real time simulation software shall simulate the power plant processes for test and engineering purpose without interference of the power plant operation. The main feature of the software shall be the



training of personal, optimization of the individual processes and to react in a real-time mode. The necessary sensors and transmitters shall be part of the scope real-time simulation. The training station shall use the same control software with all relevant functions as the operator stations.

### 11.7 Engineering Station

The engineering and configuration station shall be equipped with two monitors and a printer. At the station the following functions shall be possible, but not limited to:

- Database creation and modification;
- Mimic views creation and modification; ➤ System operation and maintenance.

### 11.8 Redundant Main Servers 1 and 2

Redundant data servers in hot standby shall be used to perform the station control functions and monitor the power plant equipment.

The data servers shall carry out the following function, but not being limited to:

- Signaling and measuring data acquisition from computers at local control level;
- Data transfer to the different sub-systems;
- Active and reactive power joint control;
- Electrical measurements and calculations;
- Remote control and monitoring of head work equipment;
- Remote control of the power plant from the LDC; □ Metering and signaling.

The primary function of the ACS in the CCR shall include, but not be limited to the following features and requirements:

- Automatic start / stop of the unit # 1;
- Load setting;
- Control of active power on the unit # 1;
- Control of reactive power on the unit # 1;
- Emergency shut down;
- Switching (on / off) of generator circuit breakers;
- Operation of switchgears;
- Operation of main AC station service main circuit-breakers.

Hard wired push-buttons for emergency shutdown of the units and emergency closing of the gates shall be mounted close to the operator stations.

A sequence of events (SOE) recording system shall be supplied to allow analysis of the reasons for the trips or plant disturbances. The SOE recorder may be either integrated in the ACS (preferred method) or be a standalone equipment. The SOE recorder shall scan all designated binary inputs continuously with a resolution of 1 MS for fast processes e.g., electrical signals and 5 MS for slow processes. The status of each point shall be time tagged and stored in a



database together with other relevant information for a specific time period. Data shall be continuously deleted from the database after the specified time period has elapsed. Facilities shall be provided for data to be archived for future reference. On the occurrence of a nominated event (e.g., unit trip) or manual initiation from the ACS, all data for the time period before the event shall be retained and continue to be recorded for a period after the event.

The SOE recorder shall automatically reset after the elapsed time period and continue to monitor the Complex in the normal way. SOE reports shall be generated and printed using the stored data and shall be used for post trip review and analysis. The report shall be presented in a clear and logical format.

#### **11.9 Interface to Office LAN and Web Client with Remote Access**

This interface with firewall shall enable communication to an office Ethernet LAN and to a web client providing a remote access function for unit and system diagnosis.

The remote access interface to the process control system shall be used to provide specialist assistance, maintenance support or for diagnosis of the ACS.

#### **11.10 Master Clock System**

The ACS requires exact time information at various stations to apply signaling time stamps accurately or to schedule time-dependent procedures.

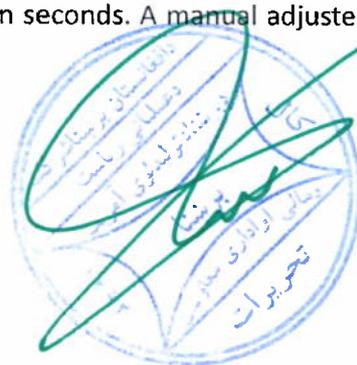
The scope shall comprise a complete functional clock system, including but not be limited to the following equipment:

- Clock system mounted in a free-standing cubicle;
- Cable distribution system with junction terminals using and extending, if necessary, the communication tray and junction system;
- Differential frequency / time indicator with automatic and manual adjuster in the control panel;
- Antenna, receiver and system interface module for receiving the international time signal (GPS) to adjust the clocks automatically;
- Output signal for secondary clock system (minute- and second-pulses).

The digital clock system shall have provision for time stamping of events with a resolution of 2 MS or better. The clock shall be synchronized by the GPS system to give an absolute accuracy of time stamps of better than 1 Ms. the antenna shall be mounted in an adequate position.

All digital control and protection systems shall be synchronized with the master clock system. The clock system shall be designed and installed as a master-slave system with independent timing and adjustment possibilities. The master clock shall be controlled by a temperature stabilized quartz oscillator with an accuracy of 0.01 s/ day producing all reference data necessary to control and supervise electronic and electromechanical time-controlled equipment.

A digital frequency differential indicator shall be installed in the control panel showing the network frequency, the quartz frequency and the difference in seconds. A manual adjuster



shall be installed; an automatic adjustment shall take place every 24 hours. The system shall work on seconds, minutes and hourly impulses. For day and month indication a memory shall be installed. The system shall be supplied by the UPS system.

#### **11.11 Redundant Gateway to the LDC**

The pertaining national specifications for power system / dispatch system interface shall be observed. Detailed data exchange requirements shall be determined during the detailed design. The gateway protocol shall be in accordance with the national protocol standards.

#### **11.12 Portable Service Station**

One industrial standard notebook computer shall be provided. The notebook shall be suitable of connection to unit via a local sub-bus system to the unit controller; or directly to the main station bus and equipped with all relevant interface and protocol software.

#### **11.13 Redundant Fiber Optic Main Gigabit/s-Bus System**

The Contractor shall define the technical requirements for all external cabling (type, repeaters, shielding, earthing, size, etc.) in order to guarantee the specified performance and characteristics according to IEEE 802.3.

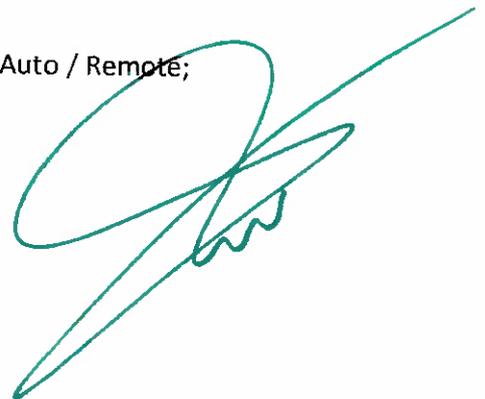
#### **11.14 Redundant Fiber Optic Process Gigabit/s-Bus System**

The Contractor shall define the technical requirements for all external cabling (type, repeaters, shielding, earthing, size, etc.) in order to guarantee the specified performance and characteristics according to IEEE 802.3.

#### **11.15 Unit LCU with Interfaces to Sub-Controllers**

As shown on the Automation and Control System Architecture Drawing, the sub-controllers shall be linked to the ACS by means of field-bus systems. **Generator Monitoring**

- Graphic diagrams showing the main circuit and GCB with auxiliary and excitation Toffs.
- Instruments for:
  - Generator current;
  - Generator voltage
  - Voltage setting;
  - MW and MVAR;
  - Synchronizer with selector switch;
  - Power factor;
  - Frequency;
  - Field voltage and current.
- Push buttons, switches and status indications for:
  - Voltage raise / lower;
  - Selector switch Local Man / Local Auto / Remote;
  - Brake ON / OFF;



- GCB ON / OFF;
- Generator auxiliary systems ON / OFF; ➤ Alarm

panel. **Turbine Monitoring**

□ Graphic diagrams showing the turbine with waterways and the generator □ Instruments for

- Speed;
- Speed setting;
- Guide vane opening;
- Opening limiter;
- Injectors in operation;
- Flow;
- Active power actual / set point.

□ Push buttons, switches and status indications for:

- Speed raise / lower;
- Opening raise / lower;
- Power raise / lower;
- Speed / opening / power control mode;
- Intake gate emergency close;
- MIV emergency close;
- Unit emergency shut down; ➤ Turbine auxiliary systems.

□ Alarm panel

**Unit MCC**

Control functions and indications shall be in accordance with the equipment PTS.

**MIV Control**

Control functions and indications shall be in accordance with the equipment PTS.

**Digital Turbine Governor**

Control functions and indications shall be in accordance with the equipment PTS.

**Static Excitation System**

Control functions and indications shall be in accordance with the equipment PTS.

**Generator Circuit Breaker (GCB)**

Control functions and indications shall be in accordance with the equipment PTS.

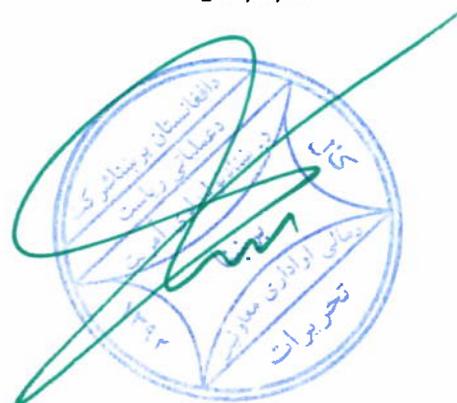
**Electrical Protection System**

Control functions and indications shall be in accordance with the equipment PTS.

**11.16 LCU for Station Auxiliary Systems**

The station auxiliary LCU shall provide the data transfer from / to the following equipment:

- MV switchgear;
- Station service and auxiliary transformers;



- LV switchgear;
- DC and UPS systems;  Diesel generating unit 1.

#### 11.17 LCU for Common Services

The station auxiliary controller shall provide the data transfer from / to the following equipment:

- Cooling water system;
- Drainage system;
- Dewatering system;
- HVAC systems;
- Compressed air system;
- Fire protection system;  Potable water system;  Sewage treatment plant.

#### 11.18 LCU for 10/110 kV

The interface and functions shall be according to the equipment PTS control and remote command functions.

The individual LCC for the generator / transformer bays, the transmission line feeder bays and the bus coupler bay shall be connected to the ACS with protocol converters (if required).

#### 11.19 LCU for the Headworks

In the headworks control building a control room (HCR) shall be provided, which is intended for independently controlling and monitoring the heads works related hydro-mechanical installations as well as the auxiliary supply systems of this Lot.

The equipment of the HCR shall mainly comprise an operator station with two monitors and alarm printer; a redundant LCU with field-bus interfaces to sub-controllers, LCC and monitors and a video surveillance system. The local control cubicles (LCC) provided with the hydro-mechanical equipment Lot 2 shall be connected to the LCU installed in the HCR by bus connections with appropriate interfaces to realise the data transfer between the headworks equipment and the ACS.

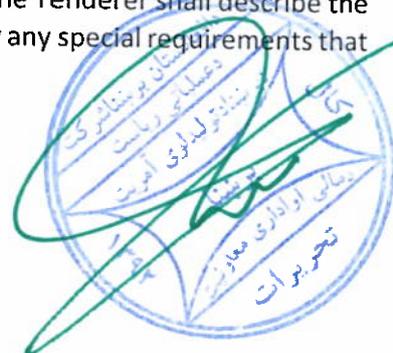
If required, the data transfer between the ACS and the LCC of the gates shall be processed via protocol converters. The interfaces shall be coordinated accordingly.

#### 11.20 CCR and HCR Furniture

The CCR and HCR shall be equipped with adequate furniture to provide ergonomically designed working places. The furniture shall comprise the following:

- Computer desks;
- Swivel chairs;
- File cabinets.

All cabling shall be appropriately installed in wiring channels. The Tenderer shall describe the proposed control and equipment room design and shall identify any special requirements that



will be needed to facilitate the complete and proper execution of the works, such as computer floor, suspended ceilings, air-conditioning, lighting, access for cabling etc.

## 12. System Characteristics

### 12.1 Self-Diagnosis Function

Malfunctions from failure of the equipment shall be indicated by annunciators operating independently from the controllers. Self-diagnosis functions shall detect failures of the following hardware (up to the printed circuit board):

- Interface module failure;
- Communication control module failure;
- Internal power supply failure;
- Software fault diagnosis: permanent on-line diagnosis of the ACS;
- Fault tolerance function and software routines shall be provided and tested.

The software shall be capable to detect functional module failures and the character of the fault.

### 12.2 Inputs / Outputs (I/Os)

#### General

The number of I/O process interfaces shall meet the requirements of the plant and 50% additional spare capacity. Hardware of I/O interfaces shall be made in a classified standard plug-in structure; the plug-in cards of identical type shall be interchangeable.

All data, control, communication and man-machine interfaces etc. shall safely withstand the following voltages:

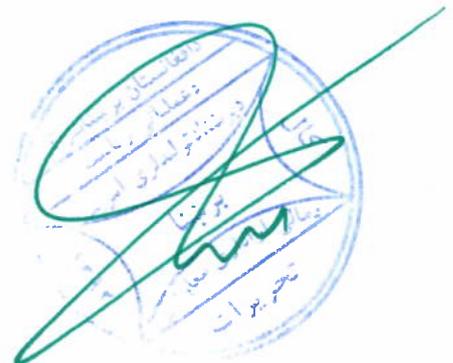
- Power frequency withstand voltage: terminals for 60 V-500 V circuits shall withstand 2000 VAC for 1 min.; terminals for circuits below 60 V shall withstand 500 VAC for 1 min;
- Impulse withstand voltage: 1.2  $\mu$ s / 50  $\mu$ s

#### Digital Input

All signal inputs shall be isolated by opto-coupler modules. The photoelectric isolator shall withstand a voltage of 1500 VAC for one minute. Hardware and software filtering provisions against the contact bouncing shall be provided.

The signal shall be valid when the duration of the contact state is 4 - 6 ms. Each digital input shall have a LED indicator, which indicates the closing of the input contact. Digital Output All digital or binary outputs shall be repeated via interposing relays. The contact capacity and the voltage shall meet the requirement of the carried load. The output relays shall be the plug-in type with dust proof enclosures. Each on / off quantity output shall have a LED indicator.

#### Analogue Input



The electrical analogue quantity inputs shall generally be 4 - 20 mA, and 12 mA at zero point for bi-directional quantities. For special inputs, 0 - 10 mA inputs shall be permissible. The analogue quantity input interfaces shall also comply with the following:

- The resolution of A/D shall not be less than 12 bits;
- Conversion precision: the error of the A/D conversion with interface shall be less than +0.1 % of full scale;
- The common mode rejection ratio shall be greater than 90 dB (DC to AC 50 Hz); □ The differential mode rejection ratio shall be greater than 60 dB (AC 50 Hz);
- Time of conversion: < 100 MS for comparative type, and < 400 MS for integral type.

### Analogue Output

The analogue output signal shall be 4 - 20 mA and the load capability greater than 500 Ω.

The conversion error from the database up to the output shall be less than ± 0.25 % of the full scale. Each analogue output shall have an independent D/A converter of 12 bits or better.

### 12.3 Response Time

Under normal conditions the response times for the operator stations shall be as follows:

- The time between selection and display, fully updated, from the database shall not exceed 2 s with a typical workstation loading of four graphic displays, two trends and one alarm display in 'windows' on the displays;
- The time between execution of a control function on an operators' workstation and the command reaching the output terminations of the station shall not exceed 2 s;
- The time between the occurrence or change of a signal at the origin and the change of state, value or alarm showing on the displays shall not exceed 2 s;
- The real time stamp of the signals shall be executed at the input to the system prior to bus transfer or signal processing.

### 12.4 Data Acquisition

The equipment in the CCR shall acquire and save to the database automatically and periodically the process parameters such as analogue quantities, on-off event quantities, statuses, etc. from the UCB, LCU or LCC via the data bus, it also receives, threshold overshoot of analogue measurements, the trend of temperature changes, etc. and shall refer them into the buffer area. The information acquired and received shall be used for updating the data base, for controlling and adjusting, for record retrieving, for operation guide, fault analyzing and repair advice etc.

The data acquisition of the ACS shall also be possible to be carried out by the operator or by the instructions of an application program. It shall realize the function of acquiring a part or whole of the parameters from a UCB, LCU or LCC or the entire boards connected to the bus, at any time.

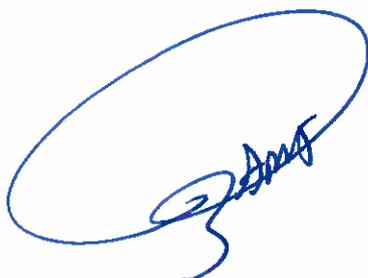


The fault alarm signal shall have first priority to transmit and the time at which the fault occurs shall be referred at the lowest level before entering the bus or field-bus system. The distinguishing time shall be less than 5 MS for important alarms. The A/D conversion precision of data acquisition of the ACS shall be 12 bits or more, the total measurement error shall be not more than  $\pm 0.15\%$ .

### 12.5 Data Processing

The ACS shall process the following:

- Check of plausibility, analysis of faulty codes and control transmission errors.
- Update the real time database of the ACS, distribute the real time data to relative stations, modify the foreseen data and the equipment states in the views to be displayed on the displays, alert the operator by displays about data with abnormal trend changes.
- Analyses of the trend of changes of some important quantities being supervised, forecast the probability of incidents, provide the operation guide. The sampling period of trend analysis may be distinct for different equipment. The number of parameters acquired in distinct sampling period shall also be different. A trend record file shall be compiled by sampling points from the real time database according to the requirement of trend recording. It shall be possible to show the trend curve on the display automatically or on demand. Measuring points displayed at the same time shall be distinguished by different colors.

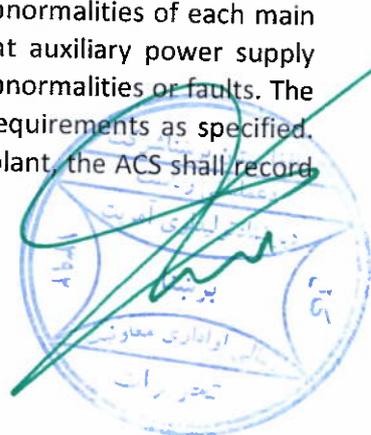


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- Monitoring of the unit bearing temperatures and trends of temperature changes of the thrust bearing, upper guide bearing, lower guide bearing and the turbine guide bearing in the starting up process. The monitoring points shall be those with the highest temperatures and points with maximum temperature change rate. The points shall be chosen by an application program or designated by the operator. The ACS shall collect and save the temperature-time curve  $T^{\circ}\text{C} = f(t)$  and compare them with the stored maximum permissible temperature rise curves. An alarm signal shall be initiated when the permissible limit is surpassed.
- Monitoring the temperature change rate of the unit bearings shall focus on the as early as possible detection of any abnormality of the equipment. The methods for choosing the points shall be the same as mentioned above.
  - Monitoring the temperature difference between the individual thrust bearing pads, compare periodically the temperature of every thrust bearing pad and compute the difference between them (or the change rate of the difference) Alarm signal shall be initiated to indicate the abnormality of thrust bearing pads, when the permissible limit is surpassed.
  - Monitoring the rate of change of the oil temperature at the top of the main transformer under different loads, with the view to discover any abnormality of the equipment as early as possible. The Contractor shall obtain the parameters, such as the permissible temperature rise curve and the permissible temperature change rate of the bearings of the unit. The Contractor shall also submit the software of trend analysis, which may be modified gradually according to the operation data accumulated after the unit has been put into operation. The initial parameters submitted, however, shall guarantee the safe operation of the unit and the MT. In addition, the Contractor may propose other effective trend analysis methods.
  - Compare the data with a pre-set threshold, initiate an alarm signal when they have overshoot, display the abnormality signal on displays or issue related alarming views on displays by the ACS automatically, and print out or record them. For the data measuring points for which the threshold overshoot checking is needed, it shall be possible to pre-set the highest threshold (HH), higher threshold (H), lower threshold (L), the lowest threshold (LL) as well as dead zone of resuming the threshold, dead zone of updating the display views, etc. When the measurements surpass the higher or the lower threshold, only alarm signals shall be issued. In case the measurements surpass the highest threshold or the lowest threshold (if such thresholds exist), a fault handling program of the equipment shall be invoked and an alarm signal sent to inform the operator. The sound and light signals of both the overshoots shall be possible to be distinguished easily by the operator.

#### 12.6 Event Recording

The events to be recorded shall be the trip signals of HV and MV circuit breakers, LV circuit breakers used for incoming feeders or bus coupling, faults and abnormalities of each main equipment, common equipment, outgoing lines and power plant auxiliary power supply systems. The events shall involve the normal operation and any abnormalities or faults. The resolution of the sequence of events recording shall meet the requirements as specified. When a fault happens to any important equipment in the power plant, the ACS shall record



the change of data of relevant measuring points prior to and after the fault and record the data of correlative quantities.

### 12.7 Alarm Management

All plant and system generated alarms shall be prioritized, logged and displayed by the ACS. There shall be a dedicated alarm display which shall show all individual and group alarms of the plant. The Operator shall have the facility to select optional alarm displays, summary of alarms, historical alarms on global or point based, unacknowledged alarms, alarms by priority, alarms by pre-defined system groups. There shall be a facility to suppress an alarm or groups of alarms as a result of a particular alarm or other plant condition in order to minimize the number of alarms under transient conditions.

### 12.8 Displays

Three displays shall be provided for each operator station in the plant control room for man machine communication and to display dynamically the views of the more important operation parameters, fault and abnormality states in figure, letter, graph and table. The diagrams shall be built up with symbols according to CENELEC, IEC and ISO standards.

All text shall be in English.

The following process diagrams shall be available as a minimum:

- Process overview diagrams, showing the main data:
  - ✓ Units running time;
  - ✓ Speed;
  - ✓ Active and reactive output;
  - ✓ Water levels;
  - ✓ Total and individual discharge; ✓ Individual system operation status.
- Overview of the station control systems.
- Overall single line diagram of the plant, showing status and electrical data.
- Single line diagram of the HV switchgear, showing status and electrical data.
- Single line diagram of the MV switchgear, showing status and electrical data.
- Single line diagram of the station auxiliary supply systems, showing status and electrical data.
- Process diagrams of the drainage system.
- Joint control.
- Total discharge calculation module.
- Process diagram for the gates and discharge control.
- Single line diagram for each generating unit, showing status and data.
- Diagram for each generator and excitation, showing load characteristic diagram, excitation diagram and data.
- Flow diagram of the cooling water system for the overall supply and for unit # 1, showing status and data.
- Threshold overshoot alarming.
- Failure in the ACS: inform and alarm immediately when following failures occur:



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- ✓ ACS unit control device failure; ✓  
ACS communication link failure; ✓  
ACS control room system failure.
- Dynamic display of the sequence of events.
- Turbine hill charts with optimized dynamic working point and actual working point and model efficiency as parameter (one to five injector operation).  
Generator capability diagram with actual working point and optimized working point and power factor as parameter.
- Periodic recording tables display the tables to be printed out periodically, including the tables of the station, the unit and other systems.
- Table of threshold setting values of supervised quantities: the dead zone for refreshing the display of each measuring point shall be able to be modified on views individually or in batches, switching on / off of each kind of measuring point (on / off inputs, analogue inputs, etc.) shall be able to be chosen on the views individually or in batches. It shall be possible to set the state or the value of the measuring points taken from the real time monitoring manually, but the display format shall be different from that of real time measuring points. At this time, the ACS shall take effective measures to ensure the safety of equipment.
- Maintenance record.
- Statistical table of number/time of operation of each equipment.
- Block diagram of computer system.
- Daily load curve of the unit
- AGC and AVC views; it shall be possible to select the functions, to assign the real time values, etc. on the view. The unit shall not be disturbed when the selected function changes.
- Statistical tables of faults, abnormalities of the power plant.

For the events of change in state, threshold overshoot, etc. the time of event occurrence, content of the event, name of the equipment and permissible operating parameters, the overshoot parameters of the equipment, etc. shall be displayed in time sequence. Images shall attract the attention of the operator by way of a change in color, change of symbols or flashing.

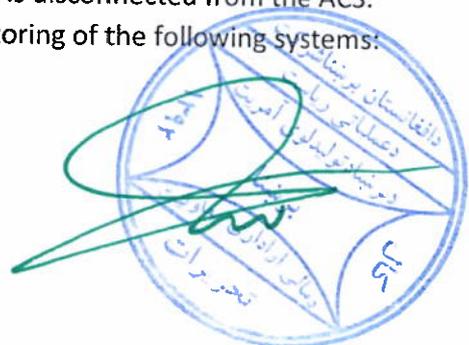
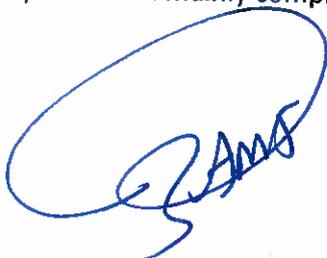
### 13. Unit Control Boards

Unit Control Boards (UCB) shall be provided with redundant controllers and redundant power supply. The UCB shall be used for automatic control of all functions associated with the MIV, turbine, generator, unit auxiliary systems, electrical protection systems and main transformer.

The scope of functions assigned to the UCB shall comprise the equipment shown on the ACS "System Architecture" drawing. Digital and analogue output signals from the unit automation equipment, resistance temperature detectors, generator excitation system, speed governor etc. shall be connected to the UCB controller. All events shall be time tagged (time-stamp) at the input card to permit easy analysis of events.

The UCB shall be designed to work independently when it is disconnected from the ACS.

The UCB system shall mainly comprise the control / monitoring of the following systems:



- Governing system;
- Excitation system;
- Mechanical protection;
- Electrical protection;
- Main transformer;
- Generator voltage switchgear;
- Interface with the ACS;
- Unit auxiliary equipment LCC; □ Unit manual control features.

The UCB shall accommodate all required equipment, instruments and apparatus to perform the following control and monitoring of the turbine-generator unit:

- Step by step and / or automatic unit starting and shut down;
- Interface to the digital turbine governor;
- Interface to the automatic voltage regulation;
- Machine loading with active and reactive power;
- Metering and recording of all characteristics of the turbine, generator and main transformer;
- Indication of normal operation of the auxiliaries essential for secure and reliable operation of the unit;
- Audible and visual warning of inaccurate operation of the unit and the essential auxiliaries;
- Audible and visual alarm and display of dangerous operation of the unit and the essential auxiliaries, or faults that may initiate tripping of the circuit breaker without shut down the unit;
- Power supply and control of essential auxiliaries of the respective unit.

The process management of the UCB shall be ensured through the local Human-Machine Interface (HMI) mounted on the cubicle's front door with protection class IP 54 or better. The local HMI shall consist of a color tactile screen. The following functions shall be available:

- Mimic diagram views;
- Process sequences follow-up for local control; □ Alarm status indication.

### 13.1 Data Acquisition and Processing

The Unit Control Board (UCB) shall contain, execute, monitor and process all equipment and functions necessary for the operation of a unit (turbine / generator set) and the ancillary systems.

The Local Control Cubicles (LCC) shall contain, execute, monitor and process all equipment and functions necessary for the operation of a sub-system and its ancillaries not directly to be related to a unit. The UCB / LCC shall realize the acquisition of any kind of analogue quantities, on / off quantities, and pulse quantities of the unit and the main transformer.

The sampling period of different parameters shall meet the specified requirements.

The following data acquisition and processing shall be realized by the UCB or LCC:

- Electrical quantities of the unit: periodical acquisition of the voltage, current, frequency, active power, reactive power, energy, operation counters / running time etc for systems / subsystems of the generator and transmission to the ACS and display.



- 
- Temperatures of the unit: periodical acquisition of the temperature of stator winding, stator core, bearing pads, bearing oil, cooling water; check if they are overshoot; send any overshoot status and data to the ACS. An alarm signal and sound (for 2 times 15 s) also shall appear on the UCB and LCC panel / monitor of the unit.
- Temperatures of the main transformer: periodical acquisition of the MT temperatures, check for overshoot and the trend analysis of temperature change and supervise the change rate, initiate the alarm and sent data to the ACS.  
Process control status scanning: acquisition and record of the status of sequence steps of the unit during the starting and shut down process and mode transition process; transmission of the data to the ACS.
- Alarm message acquiring of the unit mechanical protection: acquisition of the action message of the unit mechanical protection, send the action message of protection to the ACS and display the alarm signal with sound on UCB panel / monitor of the unit. The arrangement of various kinds of measuring points shall follow a defined format to facilitate the work of operating personnel.

### 13.2 Display and Supervision

The UCB / LCC of the unit / auxiliary systems shall have a monitor for display and monitoring. On the UCB touch panel with access to various system levels, protected by password, shall be provided. On the supervising panel / monitor, it shall be able to display the data relevant for unit operation, supervision and troubleshooting e.g., electrical quantities, temperature of the unit and main transformer, the status or data of ancillary equipment. Two display patterns shall be possible: a cyclic display and a fixed display. The scope of display and supervision shall include:

- Starting condition supervision prior to unit start-up: check whether the unit satisfies the starting condition, such as the governor oil pressure, air pressure, states of the main and ancillary equipment. If there is any anomaly, besides local indication the signal shall be sent to ACS for displaying and print-out.
- Sequence supervision of mode transition processes: supervise consecutively the progress of sequence steps of mode transitions and send the main steps to the ACS. Transfer the unit to a safe state or stop it when any impediment happens. Any operating sequence step shall have a local signal sent back to the UCB indicating step with number and clear text.

### 14. Spare Parts

The following spare parts shall be quoted by the Tenderer and included in the total tender price:

- One (1) operator station computer, fully configured;
- One (1) redundant main server core component, fully configured;
- One (1) set of interface modules, comprising 5 %, minimum one piece of each type;
- One (1) set of repeater modules, comprising 5 %, minimum one piece of each type;
- One (1) monitor of each type;
- One (1) printer of each type;



- One (1) set of interposing relays, comprising 5 %, minimum one piece of each type; □ One (1) cooling fan of each type;
- One (1) set of indicating lamps, fuses, comprising 5 %, minimum one piece of each type;
- One (1) set of MCB, comprising 5 %, minimum one piece of each type;
- One (1) set of transducers, comprising 20 %, minimum one piece of each type;
- One (1) set of printed circuit cards, comprising 20 %, minimum one piece of each type;
- One (1) set of control switches, comprising 20 %, minimum one piece of each type;
- One (1) set of push-buttons, comprising 20 %, minimum one piece of each type;
- One (1) set of instruments and meters, comprising 20 %, minimum one piece of each type;
- One (1) set of built-in stabilized power unit # 1, comprising 20 %, minimum one piece of each type.

#### 15. Recommended spare parts

The Tenderer shall recommend the spare parts he considers necessary for a 10 years operation of the equipment. These spare parts shall be quoted in the price lists but not included in the total price.

#### 16. Site Tests

##### 16.1 Pre-commissioning Tests

The following tests shall be performed during and after erection of the complete systems:

- Inspection of the installed equipment;
- Checks of the wiring of the interconnections;
- Dielectric tests and measurement of insulation resistance of each circuit;
- Functional checks of all instruments, protection relays, auxiliary relays, switches, etc. including the calibration of all gauges and instruments and relay settings;
- Functional check runs of the systems for local control and automatic control, interlocking and annunciation, etc. in operation with the actual equipment to be protected and / or controlled;
- Final adjustment of the voltage, current and time settings.

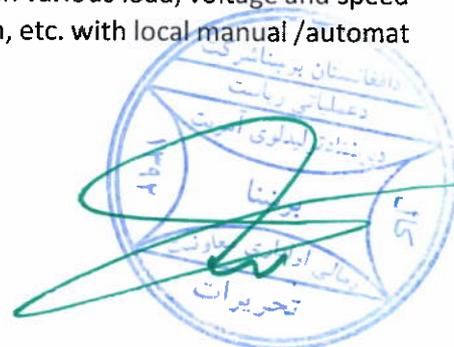
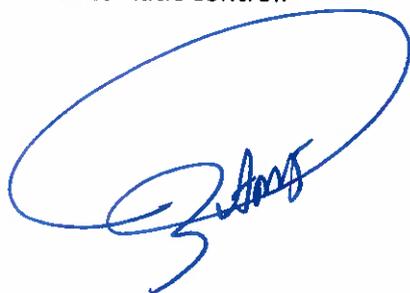
Tests of components / equipment shall be according to the Contractor's QC plans, which shall be subject to approval by the Employer.

##### 16.2 Commissioning Tests

Tests of components / equipment shall be according to the Contractor's QC plans, which shall be subject to approval by the Employer.

After installation at site and after finishing all cabling works, the Contractor shall verify all process signals and process interface. All control commands shall be executed and real process contacts and variables shall be checked. The total system performance shall be verified testing all main- and sub-routines, algorithms and control functions.

The tests of the generating unit shall include the operation in various load, voltage and speed conditions, switching on and off, starting-up, shutting-down, etc. with local manual / automat and remote automatic control.



□

All tests shall be performed by Contractor under the supervision of Employer.  
The Contractor shall arrange with the Employer the test processing details and time schedule, aiming for the tests being carried efficiently and in conformity with the operating conditions of the power plant and network.

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## Chapter 5 – Employer's Requirements

### 1. Protection systems

The relay protection systems in Mahipar hydropower plant MHPP is 24VDC old type analog systems for the power station. These systems need to be changed by optimized modern and latest systems as per international recognized standard. The Tenderer shall submit with his Tender the necessary technical brochures, design calculations, layouts and diagrams for the relay protection equipment to verify compliance with the specifications.

All equipment shall be designed according to the relevant IEC Recommendation, unless clearly stated in the Tender.

The Tenderer shall duly study the correct and safer functioning of the relay scheme as a whole, and he shall as an alternative in his Tender propose other types of relays or additional relays if he deems any of the specified relays unsuitable.

The Contractor shall provide a comprehensive relay schedule with selectivity analysis based on the network and short circuit analysis described for 110 kV and 10 kV switchgears.

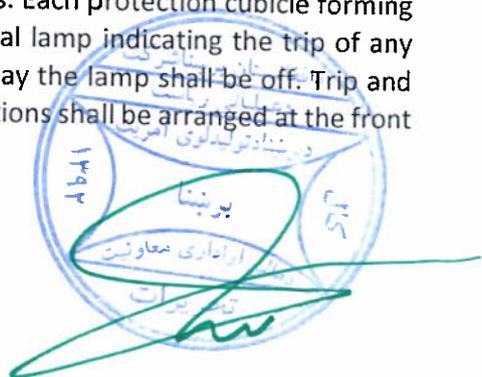
The relay protection schedule shall be subjected to approval by the Employer.

For all equipment, supply shall comprise metal enclosed cubicle assemblies with all protection relays, accessories, base frames and fixing materials and wiring complete Electrical protection systems shall be provided to isolate faulty circuits with speed and certainty, to limit damage and to maintain healthy systems in stable operation. The scope of work shall include the following protection equipment:

- the protection systems to provide the complete range of electrical protection for the generator incoming feeder
- the protection systems to provide the complete range of electrical protection for the generator outgoing feeder
- Two (2) protection systems to provide the complete range of electrical protection for the three service transformer feeders
- Two (2) protection systems to provide the complete range of electrical protection for the three outgoing feeders
- One (1) set of special spare part

### 2. Principal Design Features

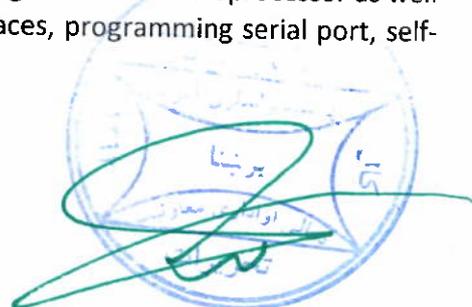
- 1) The protection systems shall be complete in every respect and include the specified protection devices, the necessary auxiliary relays, interposing transformers and power supply units. The protection devices shall be of the numerical, microprocessor-controlled type of a competent manufacturer with 5 years proven track record.
- 2) The relay assemblies shall be grouped in a logical manner to provide a good overview and facilitate the identification. Test plugs for measuring and test injection shall be easily accessible from the front side. For the power supply to each relay or group of devices redundant DC/DC converters shall be provided.
- 3) The cubicles accommodating the devices shall facilitate easy access to the wiring inside the cubicle and to the rear side of the devices. Each protection cubicle forming a functional group shall have a door mounted signal lamp indicating the trip of any protection device. After manual resetting of the relay the lamp shall be off. Trip and reset indications, adjustments and functional operations shall be arranged at the front of the protection device or cubicle.



- 4) Control circuits including potential and current transformer secondary circuits, AC/DC auxiliary power supply circuits, supervisory alarms and communication circuits associated with the function of the concerned equipment shall be protected against electrostatic and electro-magnetic influences of transients from the neighboring circuits.
- 5) All devices shall have the necessary quantity of output contacts with sufficient make and break capability, suitable for control, monitoring, supervisory and tripping functions related with the equipment. Switching of contacts in AC/ DC control circuits shall not produce harmful over voltages. CT terminals shall be shorted automatically when the relay is withdrawn from its casing.
- 6) The software for each device function shall be accessible for setting values and retrieval of events via a special software package. Each relay module shall be equipped with an integrated key pad and display. A notebook shall be included for adapting values/settings of the protection devices.
- 7) After response, the tripping contacts of the protection device shall reset automatically, however, the signaling contacts shall remain in the tripped position until the manual reset by the operator.
- 8) All relay setting ranges shall fit with the special requirements of the individual circuits. Generally, time delay modules shall have a definite time characteristic with a continuous adjusting range. Inverse time relays (10 high impedance differential relay protection Bus-bar) are likewise acceptable provided they cover a suitably wide adjusting range and ensure sufficient selectivity with other protection devices.
- 9) During the detailed design a comprehensive protection study shall be performed to define the required protection parameters, redundancies, selectivity and relay setting ranges based on the maximum and minimum short-circuit capacity of the network.
- 10) Back-up protection functions shall be properly coordinated with due consideration of short-circuit durations and appropriate time constants of the related network elements.

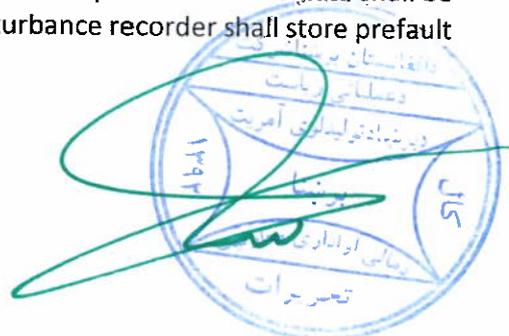
### 3. Protection Devices

- The relay assemblies shall be of modular, uniform design, accommodated as plug-in unit in standard type electronic cubicles with the systems completely wired and tested in the factory.
- The protection systems shall preferably be based on a common data bus with digital signal processing and interfaces to the primary sensors such as CT, VT and other digital sensors. For system redundancy in a centralized system two programmable microprocessors shall work on line in parallel. The individual protection functions shall be stored in a library of software which at any time can be modified and complemented with a PC with serial interfaces and recorded via a second serial printer interface.
- The protection devices may be designed with individual functions or incorporating combined protection functions in several modules, each one designed as a self-contained unit, i.e. with its own interfaces and programmable microprocessor as well as common features such as input/output interfaces, programming serial port, self-



monitoring facilities, event / alarm / tripping relays as well as event and fault recording memories.

- Functional descriptions and setting ranges of the specified protection systems are indicative only and shall be complemented and adapted by the Contractor according to his production program and to provide fully functioning, reliable protection systems.
- Protection devices shall be designed and applied to provide selectivity and maximum discrimination between faulty and healthy circuits. All devices shall remain inoperative during internal faults and transient phenomena which may arise during switching or disturbances in the system.
- The following mechanical requirements shall be considered:
  - ✓ Easy replacement of all plug-in modules, electronic cards and elements;
  - ✓ Interchangeability of the unit;
  - ✓ Easy maintenance and fault detection;
  - ✓ Silver- or gold-plated contacts of all plug-in units and devices;
  - ✓ Protection devices shall not be affected by mechanical shock or vibrations or by external magnetic fields.
- The following electrical requirements shall be considered:
  - ✓ The protection system shall be operated with analogue and binary signals by completely digital processing techniques. The input transformers shall provide the galvanic isolation between the CT, VT and other circuits and the protection devices; the signal levels shall be adjusted accordingly;
  - ✓ The protection devices shall be insensitive to voltage and current transients;
  - ✓ The devices shall operate in a large frequency range expected during start and stop of the units;
  - ✓ Simple setting by means of the integrated operation panel or with serial connected personal computer with menu-guided software;
  - ✓ The protection systems shall be based on data exchange via internal parallel bus with digital signal processing for functions, signal conditioning, analogue and digital inputs, A/D conversion, processing and signal output;
  - ✓ Communication and data exchange with the ACS shall be via serial standard interfaces and protocols in compliance with the IEC standards;
  - ✓ All protection devices shall be suitable for local and remote reset;
- The analogue measurement values of the protection functions shall internally processed, displayed and transmitted as follows:
  - ✓ Measurement value display: at the screen of the protection device or on a serial interface connected personal computer;
  - ✓ Event recording: the measurement values of the protection functions shall be stored as an event with time tagging at the moment of its occurrence;
  - ✓ Disturbance recording: the measurement values of the protection functions shall be stored as raw data or as magnitude and phase data. The data shall be sampled at 12 samples per cycle. The disturbance recorder shall store pre-fault and post-fault data.



The retrieval of the above data shall be carried out via the ACS from the CCR.

#### 4. Interfaces

The protection systems shall have the following interfaces:

- Interfaces to the protection system relevant plant components like CT, VT and other input values. These circuits shall be directly wired.
- Interface with the mechanical protection devices which shall form an integral part of the overall protection schemes.
- Standard serial interfaces with the ACS shall be provided. The communication shall be via the station bus system, utilizing standard protocols in compliance with the IEC standards. Retrieval of fault protocols and data, parameterization of protection devices and trip reset shall be considered.
- Interface to the various trip circuits. Selected protection criteria shall be directly wired to provide a back-up for emergency tripping.
- Interfaces to the T/L protection telecommunication system (provided by the transmission system contractor) shall be provided for the communication with the receiving end of the transmission lines and the transmission of tele-protection signals. The protection devices shall preferably be of the same make as those at the substations. In any case the protection systems shall be coordinated and compatible.

#### 5. Test Facilities

- The protection systems shall include self-monitoring and diagnostics, which shall operate continuously. On the occurrence of a defect and the correct operation of the protection functions are not guaranteed, the relevant protection function shall immediately be detected and an alarm given.

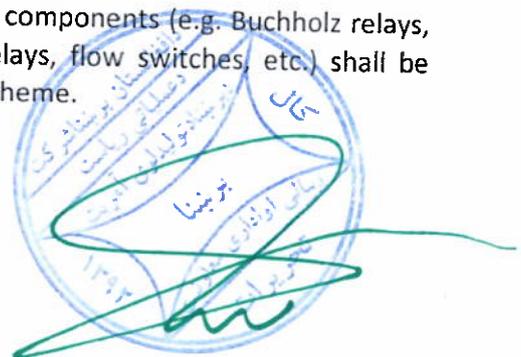
The self-monitoring and testing facilities shall provide the following routines:

- ✓ Self-monitoring of the hardware;
- ✓ Cyclically executed testing routines by means of the software;
- ✓ Viewing of the system protection parameters and values, analogue inputs and digital I/O signals;
- ✓ Injection testing with separate test equipment.

- The protection systems shall include a built-in testing facility capable of testing the protection functions from the terminal inputs of the CT and VT circuits to the output trip circuit terminals. The test facility shall be for manual / automatic operation. The automatic test feature shall include interlocks to ensure the protection of the equipment during the test process. Means for simple functional checks of the relay circuit, tripping logic and tripping auxiliary relays shall be provided.

#### 6. Trip Circuits

- Tripping schemes shall be realized by a combination of LED plug type matrix, appropriate software and directly wired trip circuits.
- External protection functions of the various plant components (e.g. Buchholz relays, temperature devices, level switches, pressure relays, flow switches, etc.) shall be integrated and further processed in the tripping scheme.



- The tripping signals of the individual protection devices shall be transmitted to the relevant tripping devices by means of the software tripping logics, the diode-plug matrix and the directly wired trip circuits. The software tripping logics shall be continuously monitored. The diode plug matrix shall be easily adaptable to changing requirements by rearranging the diode plugs. Directly wired trip circuits shall be provided for selected protection functions to be used as backup feature for emergency and quick shut down. The final configuration of the tripping schemes shall be defined at the detailed design stage.
- Trip circuit supervision shall be provided for all trip circuits. Each breaker trip coil/trip circuit shall be monitored for electrical continuity. Monitoring shall be operative with the circuit breaker in the on and off position. The trip circuit supervision relay shall feature identification of the faulty circuit and shall be time delayed to prevent operation during transient phenomena caused by breaker operation or fault clearing in the DC system.
- The trip circuit supervision relay shall initiate a delayed alarm after several seconds. This alarm shall be activated by the loss of tripping DC and by any interruption in the trip circuit wiring. In the event of a fault in any component, it shall not be possible to inadvertently trip the circuit breaker.

#### 7. Auxiliary Power Supply

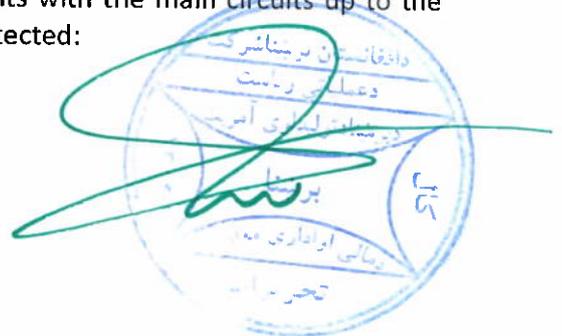
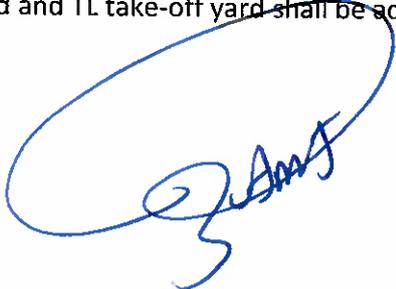
- Auxiliary power for each protection system or individual protection device shall be supplied by redundant DC/DC power units connected to the DC auxiliary supply systems 1 and 2, provided in the powerhouse and in the portal building;
- The DC/DC power units shall be natural air cooled;
- Adequate voltage monitoring with alarm annunciation shall be provided.

#### 8. Protection Cubicles

- The protection devices, auxiliary power supply units and all related equipment shall be accommodated in freestanding sheet steel cubicles of standard design with adequate space and cooling;
- The equipment shall be mounted in convenient working height. The cubicles shall have lockable front and rear doors. The front doors shall be fitted with windows providing a clear view of the interior, especially of the protection device displays;
- Protection devices related to the switchyard may also be accommodated in the LCC of the relevant feeder bay;
- Main and back-up protection systems shall be safely separated from each other. Installation in separate cubicles is preferred;
- The unit protection cubicles shall be arranged in a common assembly with the UCB;
- Protection devices for auxiliary supply systems may be accommodated in the instrument compartments of the relevant switchgear.
- Particular Design and Construction GIB (Gas Insulated Bus bar) Requirements. Generator, Main Transformer (110/10 kV YNynd5 or 11) and 110 kV cable Protection Systems

#### 9.1 General

The following equipment comprising the generating units with the main circuits up to the switch yard and TL take-off yard shall be adequately protected:



- 
- Synchronous generator;
- Excitation transformer;
- Generator bus duct systems with tie-offs; □ Main transformer with GIB termination;
- Station service transformers.

The protection systems for the above listed equipment shall be installed in cubicles, arranged in a common assembly with the UCB.

### 9.2 Configuration of the protection devices

The following protection devices shall be considered as the minimum requirement:

- Generator over flux protection
- Main transformer over flux protection
- Generator reverse power protection
- Loss of excitation protection
- Negative phase sequence protection
- Field winding overload protection
- Stator winding overload protection
- Breaker failure protection
- Instantaneous overcurrent protection excitation transformer
- Overcurrent earth fault protection MT
- Main transformer stand-by overcurrent protection
- Overcurrent protection excitation transformer
- Generator overvoltage/under voltage protection
- Rotor earth-fault protection
- Stator earth-fault protection
- Generator differential protection

### 10. Protection Systems for Auxiliary Supply Systems

The following equipment of the station auxiliary supply systems shall be adequately protected. The protection devices shall be accommodated in the unit protection cubicles and the LV compartments of the relevant switchgear, respectively.

#### Station service and auxiliary transformers

- Instantaneous overcurrent protection
- Time-delayed overcurrent protection
- Overload protection
- Earth-fault protection at 0.4 kV level
- Station service transformer differential protection

#### 10 kV Switchgear

- Instantaneous overcurrent protection
- Time-delayed overcurrent protection
- Earth-fault protection at 10 kV level

### 11. Description of the Protection Devices

#### 11.1 Over flux Protection



- The over flux protection shall protect the generator/MT magnetic core against excessive heating in case of voltage rises or frequency changes;
- The tripping delay shall be provided to prevent false tripping during transient events, e.g. load shedding;
- The relay shall be based on the principle of measurement of changes in the voltage to frequency ratio;
- The relay shall be provided with the following features:
  - ✓ V/f measurement;
  - ✓ Phase to phase measurement;
  - ✓ Maximum function;
  - ✓ Suppression of harmonics and DC components.

### 11.2 Synchro Check Relay

- Closing of circuit breakers shall be supervised by devices comparing the phasors of the two networks by phase angle, voltage level and frequency against preset values. The relay shall feature the following operation modes:
  - To fit with auto reclosing schemes requiring short dead-time intervals
  - To allow dead line/live bus check and vice versa
  - Live line –live bus
  - Live line –dead bus
  - Dead line –dead bus
  - Dead line –live bus
  - To allow manual by-pass (check function inoperative)
  - To block closing of the breaker if network phasors are out of range.
- LEDS shall be provided to indicate when the permissible limits of voltage, phase angle and frequency are within the selected range.
- The relay set shall have sufficient fine adjustment ranges to comply with the following maximum measuring variable differences:
  - Voltage  $\leq 0.3$  p.u.
  - Frequency  $\leq 0.004$  p.u.
  - Phase angle  $\leq 40$  electrical

### 11.3 Under voltage Protection

To prevent the generator from operating at impermissible low voltage, 3-phase under voltage function, frequency independent with adequate voltage and time setting shall be provided.

### 11.4 Reverse Power Protection

- The reverse/forward power protection shall detect the loss of the prime mover;
- This system shall protect the generator in the event of reverse power flow and shall be provided with time delay;
- Means shall be provided to block the operation of this relay during synchronous condenser mode;
- To validate the tripping of the 10 kV generator circuit breaker a minimum reverse power function shall be provided.

### 11.5 Loss of Excitation Protection



- This protection function shall protect the generator in the event of fault in the excitation circuit or if synchronism is lost. It shall prevent damage of the generator and power swings in the system;
- The tripping characteristic of the protection function shall coincide with the generator stability characteristics;
- To achieve a rapid and effective under-excitation protection the excitation voltage or current shall be introduced as an additional criterion. If both, the stability curve and the excitation voltage criteria are satisfactory, alarm and trip shall be triggered after an adjustable time delay of 1-2 s. The loss of synchronism with the excitation being in normal operation shall be detected by an integrator which integrates the short duration output pulses from the relay to count the short and brief power swings which, if of persistent nature, shall initiate tripping.

#### 11.6 Generator Negative Phase Sequence Protection

- In order to avoid extended heating of the rotor iron during an asymmetric loading of the generator, a negative sequence function shall be provided. Two stages, alarm and trip shall be available. This function shall have an inverse characteristic matching the  $(I_2)^2 \times t$ . The value  $(I_2)^2 \times t \leq 40$  shall be confirmed by the generator supplier;
- The pick-up current and operating time should be separately adjustable. Three-phase measurement shall be carried out;
- The definite time negative phase sequence current function shall be suitable for the protection of networks where long infrequently varying current asymmetries occur. Relatively long delays shall be allowed since the temperature of the affected rotor surface can only rise slowly.
- The negative phase sequence current protection shall be delayed in order to avoid false tripping as a result of transient and particularly asymmetrical short circuits in the network.
- The protection relay shall have a starting contact to initiate a communication prior to tripping. The pick-up current and operating time should be separately adjustable.

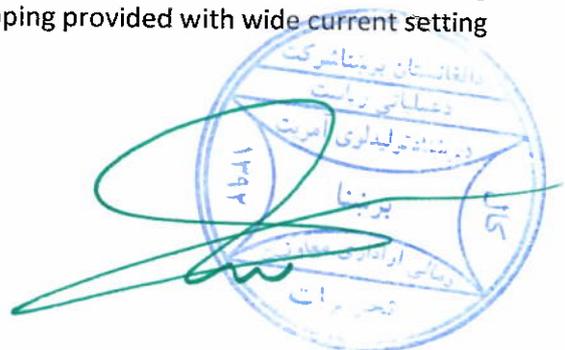
#### 11.7 Generator Over-Load Protection

- To protect the generator against overloading, single pole thermal relays having a thermal replica with adjustable heating and cooling rate should be provided. The winding temperature shall be simulated, to follow rapid changes in load. The replica element shall be designed on digital basis.
- Independent overload protection systems shall be provided for stator and rotor overload.

#### 11.8 Overcurrent Protection

Devices responsive to all 3-phase currents shall be equipped with inverse time or definite time overcurrent detection systems with adjustable time delay. They shall have the following features:

- Each phase current input shall be assigned to an individual measuring circuit for starting and delayed tripping provided with wide current setting ranges;



- The pick-up value for delayed tripping shall be set individually for each phase, with separate pick-up contacts for each phase. The pickup setting shall be widely independent of harmonics or DC off-set in the input signal;
- Individual signals shall be provided to indicate starting, tripping and blocking. Tripping outputs shall be blocked at power supply failure;
- The instantaneous tripping elements shall be suitable to be switched on or off independently;
- For TL, the relay shall be equipped with directional element;
- For protection of bus couplers, the relay shall be equipped with time delay 0.3-5 s.

#### 11.9 Stator Thermal Overload Protection

The stator overload protection shall protect the stator winding against inadmissible heating as a result of excessively high continuous overload current. The protection device shall match the machine characteristics with an inverse time thermal replica response defined by the generator supplier. Alarm and trip stages shall be available.

#### 11.10 Time- Delayed Overcurrent Protection

- The definite time overcurrent protection shall protect the MT and various parts of the auxiliary system against faults in the case the generator is disconnected;
- The measurement shall not respond to DC components and harmonics but to the power frequency component only. Connection to delta scheme CT for insensibility to earth fault on system side shall be provided;
- The delay shall enable the selectivity of the overcurrent protection. This shall be achieved by different time settings coordinated with the other overcurrent protection functions between the generator connection point and the MT. The

setting range shall adequate to detect the lowest short circuit current; ➤

The protection shall have both alarm and tripping elements.

#### 11.11 Overcurrent Earth-Fault Protection

This protection shall detect earth faults on the star-connected winding and the part of the power system connected electrically to it. The relay setting shall be adequate to protect the entire star winding. The operating time shall be coordinated with the longest time set on the earth fault protection devices of adjacent systems.

#### 11.12 Overload Protection for SST

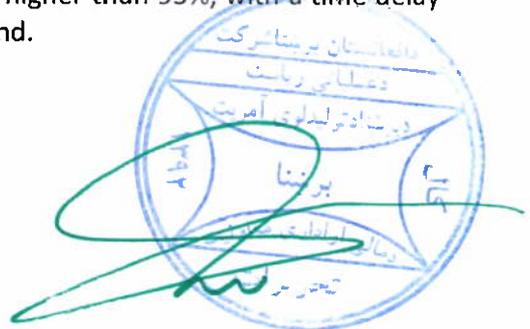
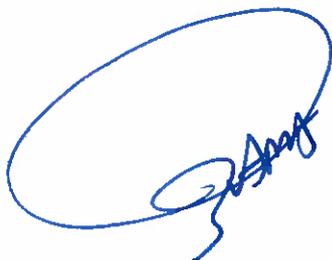
The overload protection shall be installed for the station service transformer to protect them against inadmissible heating as a result of excessively high continuous overload current.

#### 11.13 Overvoltage Protection

This relay shall protect the generator against dangerous over voltages produced within the generator.

The relay shall be of the 3-phase type with a reset ratio higher than 95%, with a time delay for the first step and instantaneous tripping for the second.

#### 11.14 Stator Earth-Fault Protection



- For faults within about 95% of the stator winding, a sensitive voltage function shall be provided. This protection for detecting the neutral displacement shall be equipped with a filter to eliminate all harmonics and shall be insensitive to phenomena other than earth faults in the stator windings (up to about 85-95% from the generator terminals). The voltages and time settings shall be independently adjustable.
- The protected zone shall be limited to 95% to avoid wrong tripping. The stator earth fault shall be either connected to the VT in the generator neutral or the VT at the generator line terminals. In both cases the devices shall monitor the neutral displacement at stator earth faults.

#### 11.15 Voltage Balance Relay

For monitoring the VT secondary circuits / MCBs or any interruption in the reference voltage circuits suitable devices shall be provided to give alarm and block the faulty operation of relays, AVR's and circuit breakers.

#### 11.16 Earth Fault Protection

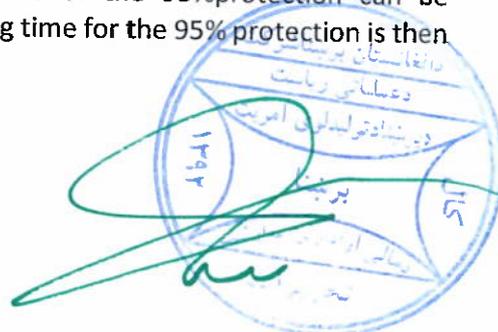
- A voltage or current sensing relay shall be provided, activated in case of an earth fault by the zero-sequence current flowing in the generator neutral grounding transformer secondary circuit together with an adjustable timer relay (95% stator earth fault protection 59NS/64S).
- For the rotor earth fault protection, a sensitive relay operating on a bridge measuring basis shall be provided. This relay shall have two response levels, i.e. ( $5,000 > R > 1,000 \Omega$ ) for alarm, and ( $R < 1,000$  ohms) for trip purposes. It shall allow the detection of a rotor earth fault even in the standstill condition of the machine and shall be suitable even for high capacitances between rotor and earth (64R).
- For transformers with differential protection and solidly earthed neutral, a high impedance directional relay for comparison of the line and neutral current flow shall be provided (64T)

#### 11.17 Rotor Earth-Fault Protection

For rotor earth fault protection in case of single ground fault a sensitive voltage function operating with auxiliary equipment should be provided. This function shall provide two detection levels, one for alarm and one for trip purposes. The relay shall be insensitive against harmonics and shall not be influenced by earth capacitance or other interferences.

#### 11.18 100% Stator Earth Fault Protection

- This protection shall cover 100% of the stator winding and consist of a 95% measuring element and an additional element covering 95-100% of the winding. Its application shall be based on availability of a minimum 1% third harmonic voltage at the neutral;
- When more than the minimum 1% third-harmonic voltage exists, the operating zone of the third harmonic 95-100% protection can be further extended and the set operating value of the 95% protection can be increased. A reduction in the operating time for the 95% protection is then feasible without any loss in reliability;



- The third harmonic detector shall be supervised by either a generator phase-to phase voltage, or generator current. The third-harmonic relay setting shall be determined from the amount of generator neutral third-harmonic voltages. When voltage supervision is used, the 100% protection shall be provided even during startup, when the voltage is above the supervision relay operation level.

#### 11.19 Over/Under Frequency Protection

This protection function shall be used as a back-up protection in case of voltage reduction during parallel operation. The setting shall be coordinated with the under-frequency load shedding in the network. The device shall have three individually adjustable frequency and time setting steps. The frequency setting shall be in 0.1 Hz steps with 0.03 Hz accuracy (As per DABS request)

The device shall be operative between 0.9 and 1.1 p.u. rated frequency (As per DABS request).

#### 11.20 Generator Differential Protection

- The generator differential protection shall be applied for the protective zone of the stator in the case of short-circuits for fast selective and sensitive protection;
- The protection function shall be an instantaneous percentage-differential type with suitable biased characteristic. The measurement system shall be 3-phase, low impedance principal. Three phase and phase to phase faults shall be detected. The generator differential protection shall include stator winding and generator terminals and 10 kV side of the excitation transformer;
- The generator differential protection shall have the following properties:
  - High stability for external faults and CT saturation,
  - Very short operating trip time;
  - Suppression of DC-current and harmonic components; - Non-linear current dependent trip characteristic.

## 22. Spare Parts

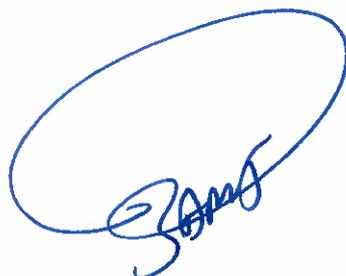
- One (1) complete generator numerical relay;
- One (1) lot of electronic cards related to the measuring, processing and trip circuits of protection devices, comprising one (1) piece of each type;
- One (1) lot of electronic cards, trip relays, and other circuit components other than for protection devices, comprising one (1) piece of each type;
- One (1) lot of DC/DC converters, power supply filters and other power supply units, comprising one (1) piece of each type.

#### 22.1 Recommended Spare Parts

The Tenderer shall recommend the spare parts he considers necessary for a five years operation of the equipment. These spare parts shall be quoted in the price lists but not included in the total price.

#### 22.2 Special Tools and Appliances

One (1) Automatic Testing Facility



The automatic testing facility shall test each of the protection devices in turn and be capable of measuring all pick-up values, phase relationships of all the analogue inputs and time delays. The testing values shall be printed out by a printer forming an integral part of the test set.

The accuracy of the measurement performed by the automatic testing shall be better than +2%

The automatic testing set shall have the additional possibility of comparing the measured values with a stored record of the actual settings. It shall be possible to start the testing cycle either manually or automatically by a digital clock incorporated in the test set. One (1) Laptop The laptop with serial interface shall be suitable for engineering and maintenance work with all components of the protection systems.

### 23. Workshop Tests

#### 23.1 Type Tests

All protection devices and individual components shall be type-tested products of competent manufacturers. Type test certificates shall be provided.

#### 23.2 Routine Tests

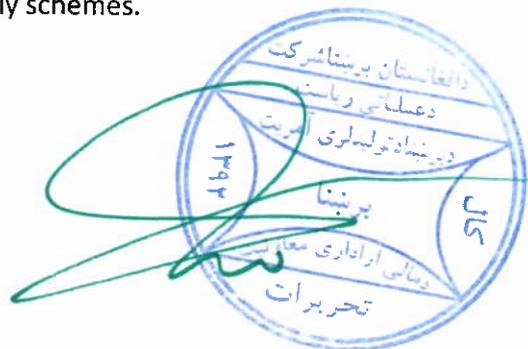
- Prior to assembly in protection cubicles, the components shall be tested according to the certified QC plan and the relevant standards.
- The completely assembled protection cubicles shall be tested according to an approved QC plan and the relevant standards.
- The following tests shall be carried out in the presence of the Employer:
  - Visual inspection, verification of corrosion protection
  - Dielectric tests
  - Functional tests of all equipment

The individual functions with actual settings of the protection devices shall be demonstrated by application of an injection type test set.

#### 23.3 Site Tests

The site tests shall be carried out according to an approved QC plan, including the following as the minimum requirement:

- Verification of the completely installed protection systems;
- Verification of the cabling by the Contractor. Random tests shall be carried out in the presence of the Employer;
- Dielectric tests of auxiliary power supply, control, measuring and protection circuits;
- Testing of the protection devices and verification of all protection settings in accordance with the protection setting calculation;
- Primary injection tests with fault simulations; testing of the tripping circuits and logics;
- Functional tests of control, interlocking, measuring and signaling circuits;
  - Tests of redundant power supply schemes.



## 2.1 Distribution Panels AC and DC

The supply shall include a sufficient number of distribution panels, each supplied from the station supply switchgear.

## 2.2 Cables and Wiring, etc.

- One lot of power cables from the station supply switchgear to the distribution panels.
- One lot of cables and wiring from the distribution panels to all lighting fixtures, socket outlets and panel heaters.
- Necessary cable trays and plastic ducts, clamps etc. for a complete installation.

## Chapter6 – Employer's Requirements

### 1. Technical Documentation and Training Program

#### 1.1 Contractor's Drawings and Documents

It is obligation of the Contractor to prepare all of the drawings, reports and manuals necessary for the project implementation; this documentation shall be submitted for approval at the due time in accordance with the contractual time schedule of the works, in such a way not to cause delay to the works, and with a reasonable rate of submission in order not to concentrate too many documents in single submissions. When the Contractor prepares his detailed time schedule, he shall make allowance for and indicates the dates expected for submission of drawings and other documentation to the Employer. A dedicated time schedule of the submittal of the documentation and the detailed time schedule shall to be prepared by the Contractor as soon as the Contract is signed, and shall be sent to the Employer for approval within 30 days from the Date of Signature of Contract Agreement.

All drawings/documents shall be presented in digital format (in pdf and dwg format) and files transmitted by e-mail by the Contractor according to a procedure "Codes and Standards". Three (3) copies of approved drawings/documents, including manuals, shall be also submitted to the Employer printed on durable paper.

As soon as erection of the Plant is complete, the Contractor shall supply to the Employer a digital copy in PDF of each drawing/document, a digital copy in DWG format of each drawing and three (3) copies of all "As-Built" drawings/documents, even if the same document was previously approved and no modifications were made during erection. These copies shall have been updated, where necessary, to represent the as-built work as erected, and shall be marked with an "As-Built" stamp.

Style of the drawings/documents shall be in accordance with the best international practice, shall be complete with all the data and made as indicated below.

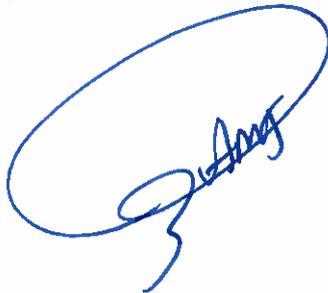
The general assembly drawings shall be completed with the list of sub assembly drawings. The subassembly drawings shall be completed with the list of components' drawings and/or dimensions and materials of components.

The component drawing shall be completed with all indications of materials.

Commercial items shall be clearly identified.

Lists of materials, components, etc.... may be separate from the drawings but shall be attached to them. The drawing without list or attached list shall be rejected.

The drawings shall indicate the net weights of all items.



The drawings shall be well readable, background shall be white, and well readable colors, or black color, shall be used for lines and words.

Areas shall be properly identified in the drawings in order to allow to easily understanding what is empty and what is full.

All welds shall be shown in the drawings. Drawings relevant to single piece composed of various elements shall show all necessary welds. It is admitted in a general layout not to show welds and this case a piece composed of various welded elements shall be show as a single piece. The same piece shall be than represented in a separate drawing where all welds are shown.

Only existing lines of the pieces and quotation lines shall be present on the drawings; that is drawn only to speed up the execution of the drawing, will not be accepted. Quotation lines and tolerances shall be indicated in the drawings and thickness of quotation lines shall be smaller than those of the piece.

Dimensions on all drawings shall be in metric system.

Drawings and documents shall include the "Title block" as indicated in "Codes and Standard" procedure.

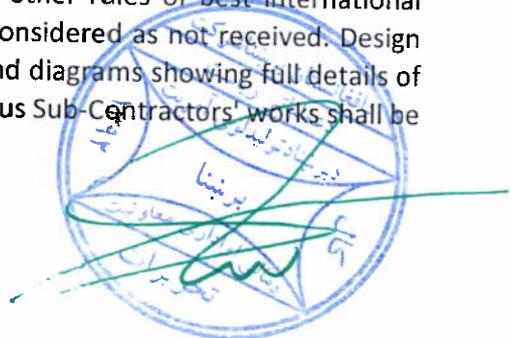
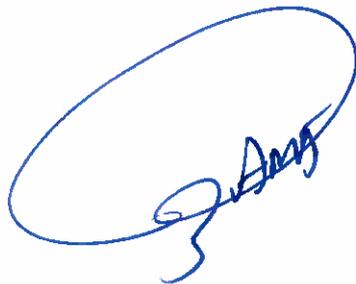
Coding of the documents and drawings is specified in "Codes and Standard" procedure: each document is assigned a unique ID number that must follow the syntax indicated in "Codes and Standard" procedure. Note that the procedure also allows to specify, in a separate field, the document number that the supplier might assign to the document according to his internal procedures.

Sections shall be properly identified and represented. For example, superimposition of two or more sections shall not be allowed. Layout drawings shall be prepared and submitted using software which identifies with different layers the various systems of the layout; layers shall be easily identified and each may be switched on/off when examining the drawing. List of layers which will be used shall be subject to approval. In the layout each component shall be identified with a number/code and the layout shall be accompanied by a list where the identification number/code, quantity and reference detailed drawing or catalogue code of each item is indicated.

Systems included in a general layout, such as air and oil systems of the powerhouse shall be properly represented on the general layout and no separate layouts will be accepted as well as no separate layout of piping and cable routes. Drawings shall be made in such a way to make possible, when printed, to easy read them, taking into account that the maximum printing format will be DIN Standard size A0. The Contractor shall submit to the Employer with or before the drawing of the corresponding piece the appropriate calculations proving the correctness of the data shown on it. The calculations shall be made in accordance with the requirements of these specifications and applicable standards.

The erection drawings shall show the foundation details and the position of all rods, pockets, bolt holes and the provision for grouting, etc. They shall include details of parts to be built into and loads to be transferred to the civil works, description of erection methods and details of connections if any to any other equipment.

Drawings and documents not respecting the above and other rules of best international practice will be rejected without comments and will be considered as not received. Design criteria, calculations, dimensioned and traced drawings and diagrams showing full details of the Plant and materials and arrangements related to various Sub-Contractors' works shall be



submitted by the Contractor for approval. One copy of the submitted drawings will be returned to the Contractor with one of the following stamps: "Approved", or "Approved Except as Noted" (authorizing the Contractor to proceed with the Contractual Works taking account of the Notes) or "Returned for Correction and Resubmission". Wherever possible only the notes on the corrections to be done shall be returned to the Contractor. In every case, these drawings, etc., shall be submitted in sufficient time to permit modifications to be made without delaying the completion of the Works. Drawings to be modified as required by the Employer shall be resubmitted for approval and the modifications shall be clearly identified.

After approval of drawings by the Employer, the Contractor shall furnish the Employer an updated edition immediately after any revisions. No major revisions shall be made after approval of a drawing without resubmitting the drawing for formal approval of the said revision. Any manufacture, assembly or installation of Works or portions thereof prior to the approval of pertinent drawings shall be at the Contractor's risk. Drawings submitted for reference shall be submitted in the same manner as approved drawings. Should any modification be required, the Employer may instruct the Contractor to do so, and the drawings so modified shall be re-submitted. Details of foundation loads and forces to be supported by the concrete structure shall also be provided.

The Contractor shall be responsible for any errors or omissions in the Contractor's drawings. Approval by the Employer of the Contractor's drawings shall not relieve the Contractor from any responsibility under the Employer nor shall it be construed as permitting any departure from the Contract requirements.

Approval of Contractor's drawings shall not relieve the Contractor from the responsibility for any error which may exist, and he shall be responsible for dimensions and detailing of adequate connections and of agreement between the dimensions and details, and satisfactory manufacture and performance of all Works. All cost for preparation, submittal, modifications and re-submittal of all documents and information required under this Contract shall be deemed to be included in the Contract Price.

### 1.2 Documentation to be submitted

Unless otherwise specified in the Particular Technical Specifications Electro-Mechanical Facilities and Particular Technical Specifications Hydro-Mechanical Facilities or otherwise agreed, the Contractor shall submit the following documentation to the Employer for approval: The documentation is listed hereinafter starting from the most urgent documents and ending with the last ones. a) **General data**

- ✓ Quality Control Plan
- ✓ Detailed schedule, containing design and manufacturing, shop tests, delivery, erection and commissioning
- ✓ Principle drawings and schematic diagrams
- ✓ Preliminary type test reports and literature on standard equipment
- ✓ Preliminary lifting drawings for erection
- ✓ Electrical power requirements during erection
- ✓ Program of performance tests, material and shop tests to be carried out ✓ Drawing classification plan.
- ✓ Project Control data





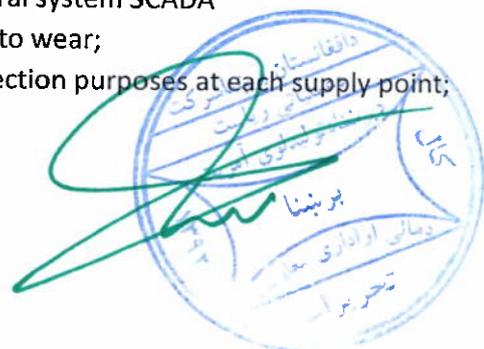
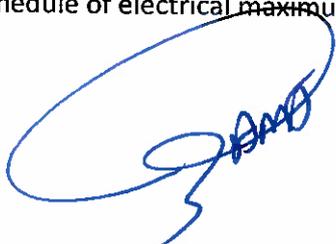
- ✓ Unit start – stop sequences, functional schemes for the protection, control and monitoring equipment, functional schemes of the main auxiliary systems, etc.;
- ✓ Magnitudes and directions of all forces to be transmitted to the foundation of all equipment;
- ✓ Quality Control Plan for Factory Inspections;
- ✓ List of sub-orders
- ✓ Dimensioned drawings of all embedded parts;
- ✓ Crane erection information;
- ✓ Preliminary calculations for the dimensioning of the complete power station earthing system;

**d) General design:**

- ✓ Calculations of stability and regulation characteristics
- ✓ Over-speed and pressure transient calculations
- ✓ Electro mechanical design of, turbine, gates.
- ✓ Preliminary drawings of the methods of anchoring and supporting all embedded parts;
- ✓ Schedule of water supply demand for all systems under the Contract;
- ✓ Expected sound pressure level curves versus frequency for the generator;
- ✓ Final arrangement and assembly drawings of the powerhouse complex, showing construction of main components, leading dimensions and masses and confirmed locations;
- ✓ Final design calculations to prove the structural integrity of all plants and to confirm that the plant complies with the guaranteed performance as described in the schedules attached to these requirements;

**e) Detailed design:**

- ✓ Preliminary list of all proprietary items giving make, type and performance data;
- ✓ Preliminary schematic drawings and circuit diagrams of all pneumatic, hydraulic and electric control and auxiliary systems including auxiliary supply circuits at each voltage with their current ratings;
- ✓ Rating and starting current of all motors;
- ✓ Final drawings of the methods of anchoring and supporting all embedded parts.
- ✓ Detailed manufacturing drawings with all important dimensions, final assembly drawings, governing and control schemes, tubing and piking schemes cabling and wiring diagrams and block and circuit diagrams intended to aid understanding and to provide full information about the principles of operation
- ✓ Performance and stress calculations as the Employer may require
- ✓ Critical speed calculations
- ✓ Detailed information (type, make, etc.) on products used for priming and painting of all components
- ✓ Electromechanical design of generator, powerhouse apparatus
- ✓ Functional and electrical drawing for architectural system SCADA
- ✓ Final detail drawings of all components subject to wear;
- ✓ Schedule of electrical maximum demand for erection purposes at each supply point;



- ✓
- ✓ Preliminary wiring diagrams and arrangements of the electrical equipment, plant and cubicles.
- ✓ Preliminary cabling schedules and termination diagrams;
- ✓ Final material Specification for all main components;  
Detailed plant and building fire detection and protection design.

**g) Data for installation, operation and maintenance:**

- ✓ Final sub-assembly and detailed drawings for the proper installation, maintenance and operation of the Plant and for identification of parts;
- ✓ Final list of all proprietary items giving make, type and performance data;
- ✓ Final schematic drawings and circuit diagrams of all pneumatic, hydraulic and electric control and auxiliary systems including auxiliary supply circuits at each voltage with their current ratings;
- ✓ Draft of the complete operation and maintenance instructions.
- ✓ Quality Control Plan for Site Inspections

**h) Within 30 days following the Employer's request:**

- ✓ Revised drawings, Specification and data sheets
- ✓ Any revised information which has not been approved earlier by the Employer i)

**During manufacture:**

- ✓ Progress reports at monthly intervals
- ✓ Notices of tests and shop inspections
- ✓ Inspection reports
- ✓ Certificates of tests and inspections

**j) Not later than 30 days before shipment:**

- ✓ Loading lists of each consignment
- ✓ Instructions for loading, unloading, handling, and precautions for the storage on Site

**k) Not later than 90 days before commencement of turbine and generator erection:**

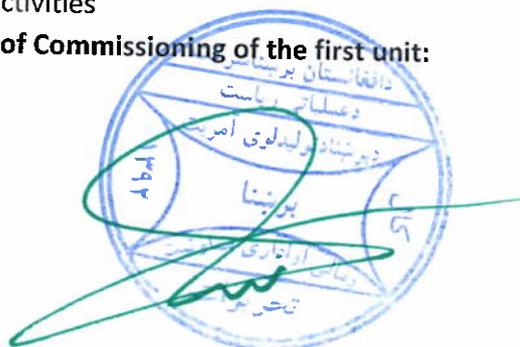
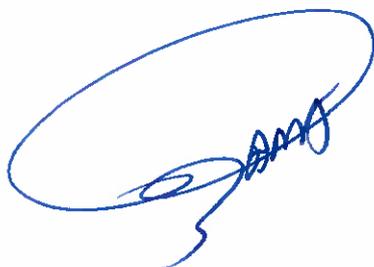
- ✓ Installation drawings, detailed circuit diagrams and protection study of powerhouse apparatus
- ✓ All erection procedures and instructions
- ✓ All approved drawings
- ✓ List indicating the special lifting devices and special tools
- ✓ Detailed erection program
- ✓ Inspection program indicating main activities of inspection, including a site test schedule
- ✓ Preliminary operating and maintenance manuals

**l) Not later than 30 days before commencement of erection all policies of insurance related to the site work.**

**m) During erection:**

- ✓ Progress reports at monthly intervals
- ✓ Work log book reporting on the day-to-day activities

**n) Not later than 180 days before Commencement of Commissioning of the first unit:**



- ✓
- ✓ Tentative manuals, containing detailed program and description for commissioning tests for each section
- ✓ The "Commissioning Manual"
- ✓ The "Operation and Maintenance Manual"
- ✓ The detailed instructions, conditions and procedure of trial operation

**o) Before Taking-Over of the Works:**

- ✓ "As Built Drawings/Documents", electronic version on CD
- ✓ Final commissioning report and commissioning manual updated with data added during commissioning
- Final operation and maintenance manuals."

**2. Installation**

The Supply shall include the complete erection of all the equipment. An indicative erection program shall be included in the Tender, based on the prevailing working hour regulations. Duration in weeks for the different activities shall be stated in the program. The Contractor shall describe his recommended erection procedure.

The Contractor shall provide all items required for the handling during shipment to site and during installation, assembling, dismantling and erection of the equipment etc. as required. The Contractor will provide electric power at site. The Contractor shall state his need in the Tender.

The Supply shall include all the devices necessary to carry out the erection according to the best practice. The Supply shall also include all the temporary supporting structures necessary for the storage, preassembly and assembly of the equipment unless such structures are specifically indicated in the Contract Documents to be supplied by others. All the parts to be filled with oil, such as bearings, tanks and relevant piping, shall be cleaned by oil flushing before the first filling. The oil for the flushing and relevant equipment shall be included in the Supply as well as the oil and the grease for the first filling.

The equipment shall be installed keeping the dimensional tolerances. Therefore, the Contractor shall detail in the Installation Drawings and Instructions the installation tolerances necessary to obtain, keeping into account the manufacturing tolerances, the prescribed tolerances according to Standards and/or his practice.

All the tie rods, foundation bolts, anchoring beams etc. necessary for fixing the equipment to the concrete and/or for transmitting to it the relevant loads, shall be supplied by the Contractor. The supply shall also include all the provisional or permanent devices for levelling the equipment and all the provisional or permanent stiffeners necessary during concreting.

**3. Pre-Commissioning and Commissioning**

Pre-Commissioning is intended as the ensemble of all the testing, checking and other requirements to be carried out at the Site by the Contractor in preparation for Commissioning in accordance with the General Conditions of Contract. The Recommissioning is intended to demonstrate the Completion of Facilities, both structurally and operationally. The Contractor shall check the electrical and control circuits, calibrate the instruments, clean the equipment and flush the lines, check lubricants and filters, verify the adequacy and correctness of the manuals and certificates and present a list of minor works to be completed (punch list) in order to have the plant in perfect conditions to start the Commissioning.



✓

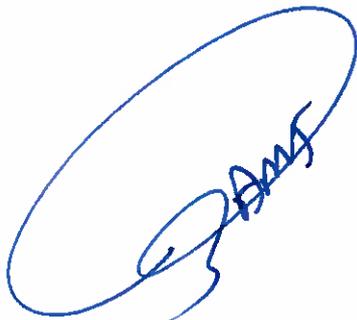
The pre commissioning tests listed here are mainly referred to auxiliary systems, while for the main equipment reference shall be made to the particular requirements included in other part of these specifications.

**3.1 Materials and Tools**

The Contractor shall supply electricity, water, fuel, lubricants and all necessary consumable materials for the tests at Site. Measuring, testing and communication equipment and tools shall be made available by the Contractor.

**3.2 Pre-Commissioning Manuals**

The Contractor shall prepare and submit to the Employer a "Pre-Commissioning Manual". The Pre-Commissioning instructions shall describe all the procedures in sufficient detail for testing each component and for calibration of the instruments.



The main purpose of the Pre-Commissioning instructions shall be to:

- Facilitate the co-ordination of the Pre-Commissioning of the Plant by making clear the necessary work steps;
- Provide means of recording and monitoring of the progress of Pre-Commissioning activity;
- Ensure that full records are made of the Pre-Commissioning work;
- Identify the procedures used to ensure safety during the Pre-Commissioning activity. Pre-Commissioning tests and inspections to be carried out by the Contractor shall include but not be limited to all the items specified herein under and all site tests depicted in other parts of these specifications.

### 3.4 Pre-Commissioning Plan

The Contractor shall prepare a detailed Pre-Commissioning plan including critical path chart and associated Gantt chart showing the sequence in which pre-commissioning activities will be carried out.

The Pre-Commissioning plan shall include also all activities to be completed by third parties so to enable Pre-Commissioning activities to proceed as planned. The plan shall be submitted to the Employer for review and approval.

The Contractor shall give reasonable advance notice of each Pre-Commissioning test and inspection to the Project Manager. The Employer, the Project Manager and/or their designated representatives shall be entitled to attend all Pre-Commissioning tests and inspections.

### 3.5 Test Reports

Certified reports of all tests and inspections shall be prepared by the Contractor, duly filed and made available to the Employer. At Employer's demand they shall be submitted after the completion of each test. Should results of the site tests show discrepancies between information stated on the technical documents and the Plant, and in the case the material or equipment as built is accepted by the Employer, the Contractor shall update the documents with the results of the tests. The Contractor shall carry out additional tests that may be reasonably required by the Employer to prove that the installation entirely fulfils the technical requirements.

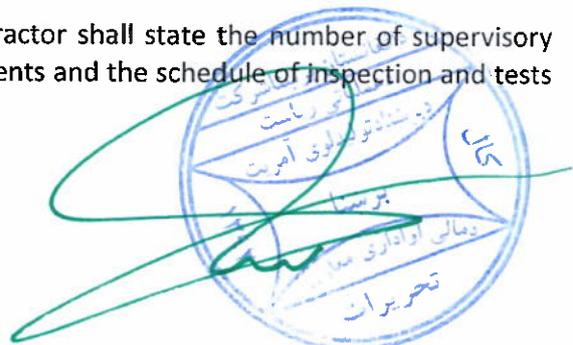
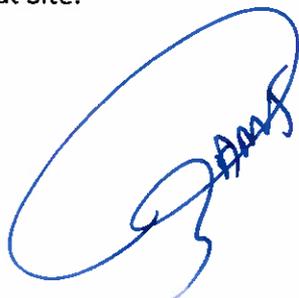
### 3.6 Instruments

All measuring and testing equipment used in tests shall be calibrated and adjusted against certified equipment having a known valid relationship to internationally recognized standards.

The Contractor shall prepare a calibration schedule showing equipment type, identification number, location, frequency of checks, method of checking and action to be taken when results are unsatisfactory. Each piece of equipment shall be labelled with its identification and current calibration status. Calibration records for each piece of equipment shall be maintained at least for the life of that piece of equipment and shall be available for examination by the Employer.

### 3.7 Personnel

The QA/QC plan to be submitted by the Contractor shall state the number of supervisory personnel, their respective specialized assignments and the schedule of inspection and tests to be carried out at Site.



### 3.8 Mechanical

#### 3.2.1 General

- Check each pipe or sector for correct installation of controls, instrumentation, valves, drains and vents;
- Stroke all valves fully. Check limit switches and positioners, where applicable;
- Check and adjust safety valve settings;
- Check and adjust protective device and interlock settings;
- Check correct reliable functioning and calibration of all automatic controls, instrumentation, supervisory equipment and manual controls;  
 Lubrication verification (both quantity and grade of lubricant);  Check all bolting is correctly tightened.

#### 3.2.2 Pumps and Associated Liquid Piping Systems

Bumping each pump motor to check rotation shall be done with the coupling disconnected to prevent spinning impellers off the shaft. Coupling alignment shall be checked against manufacturer's recommendations. Mechanical seal lines shall be thoroughly cleaned and flushed. Bearing lubrication shall be checked and filled in accordance with the manufacturer's instructions. If possible, each pump shall be rotated at least one revolution by hand to check for absence of interference. Alignment shall be checked with the pump unbolted from piping and also bolted to piping, with at the Employer's presence. Minimum flow recirculation lines shall be open before starting the pump.

#### 3.2.3 Steel Pipework

##### Hydraulic Test

On completion of erection, steel pipework shall be hydraulically pressure tested at 1.5 times the design pressure (minimum) for 30 minutes.

Pressure shall be raised in 7 bar stages and no leakage of any entity shall be detected.

##### Hot forming operations

Temperature records of hot forming and heat treatment operations, shall be made, filed and submitted to the Employer.

The wall thickness of hot formed bends shall be checked by an ultrasonic method. Records of these tests shall be kept and made available to the Employer. All radiographic examinations, including any additional tests that may be required shall be at the expense of the Contractor. Where random radiography is specified, this shall refer to the final weld only, and shall be at Employer's selection and discretion. For the purpose of radiographic inspection, a root pass is defined as the first complete weld run. Blanking-off pieces shall be made available on site by the Contractor.

#### 3.8.4 Fire Fighting

- Visual inspection of the fire equipment to check the conformity of the installation with the schematic's diagrams and the arrangement drawings

The following supporting documents according to QA/QC standards shall be submitted:

- Certificate of conformity for the fire detection system components,
- Certificate of conformity for the fire extinguishers,

#### 3.9 Electrical



### 3.9.1 General

Before electrical systems are energized, the Contractor shall perform complete electrical tests including, but not limited to, the following:

- Re-tighten and verify torque of all terminal connections on low and higher voltage systems;
- Megger and/or Hi-pot switchgear, bus, feeders and cable on 400 V and above;
- Circuit Breaker Testing: for all circuit breakers 400 V and above, verify breaker alignment, mechanical operation, timing tests, lug tightness, contact resistance and insulation resistance. Correctly set and record all trip set points on all protection relays;
- Control and Protection: Protection tests shall be performed to prove correct operation and settings. All functions of protective devices and control circuitry shall be verified by complete operational testing;
- VT's and CT's: Perform ratio, polarity, burden saturation and Megger tests on all CT's. Perform ratio, polarity and Megger test on all VT's;
- Motors: Megger and verify correct operation/calibration of any protective devices; Installation testing, equipment pre-commissioning, subsystem and system testing shall be ordered and arranged such that any disconnections, rearrangements, readjustments etc. required cannot invalidate previously completed testing. If this cannot be achieved any affected previously completed tests shall be repeated.

### 3.9.2 Medium Voltage Switchgear

After completion of the erection, each metal-clad unit shall be submitted to the following tests:

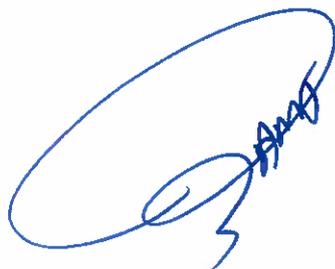
- Verification of the proper and complete erection;
- Verification of the proper condition of insulators, sealing and external surfaces;
- Verification of the proper connections to the grounding system;
- Checking of the proper cabling and operation of auxiliary circuits, protection, and settings;
- Verification of the correct polarity and secondary wiring connections of current transformer and voltage transformer;
- Verification on the correct operation of the interlock.

### 3.9.3 Low Voltage Service System

After installation on Site all equipment, where applicable, shall be dielectrically tested and shall be operated to prove that the operating gear, starters, contactors, tripping devices, protective gear, and interlocking are satisfactory and primary and/or secondary injection tests shall be carried out on all protective equipment. The Contractor shall provide all test equipment.

The following, but not limited, Site tests shall be performed to ensure a satisfactory system:

- Mechanical Tests:
- Insulation Resistance test;
- Point to point wiring continuity checks on all circuits to confirm the final connection agree with the panel wiring diagrams;
- Loop test
- AC and DC test
- Energizing of all circuits;
- Check operational of all relays, instruments, alarms and trips;



- Adjustment of all relays in line with the setting to be agreed with the Employer.

### 3.9.4 Motors

Insulation resistance test, and phase rotation checks shall be undertaken on all motors.

### 3.9.6 DC Distribution Panels

Routine Tests performed at workshop shall be performed again after all cable's connections are completed.

### 3.9.7 Cables and Accessories

The Contractor shall carry out the following tests:

- Line to line insulation tests on all cables;
- Continuity tests on all cable conductors and shield;
- AC test voltages according to standards

The Contractor for the grounding system hereinafter shall carry out the following tests:

- Ground conductor continuity check;
- Grounding resistance measurement;
- Step Voltage measurement; □ Touch Voltage measurement.

### 3.9.11 Protection System

The Contractor shall carry out the following tests:

- Secondary Injection. It shall be carried out on all relays using voltage and current of sinusoidal wave, form and rated power frequency with the aim to check to correct intervention of the protection relays.
- Primary Injection. This test has the aim to check the continuity and polarity of secondary amperometry circuits.

### 3.10 Controls and Instruments

The Contractor shall provide all test and configuration equipment for pre commissioning of the entire control and instrumentation system.

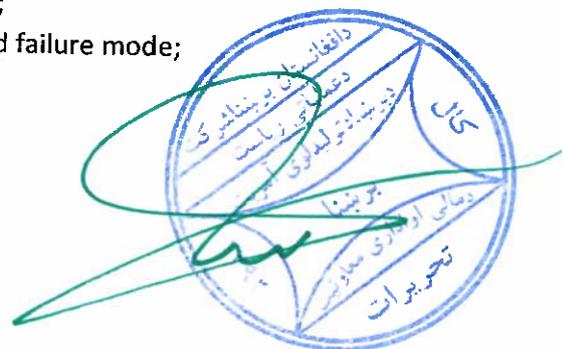
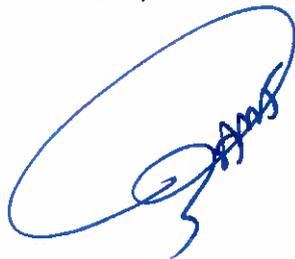
Before any Plant system is put into service, instrumentation calibration and loop checks shall be completed. The Contractor shall use trained personnel to perform all instrumentation calibration to include but not be limited to: field transmitters, valves, local controllers and control units, all electrical protection testing and calibration and all electrical interlock checks to include but not be limited to motor permissive circuits.

Self-actuated pressure and temperature regulators shall be checked and set in the field after they have been permanently installed. Thermowells shall be checked for conformance to specifications with regards to materials of construction, length and proper installation location.

Float-type devices shall be checked in place.

The Contractor shall perform loop checks to verify that all loops function as designed. A loop defined as two or more devices acting in unison for a single function, such as the Plant Control and Monitoring System. Other checks shall include:

- Temperature sensing device type;
- Instrument cable termination/shielding;
- Valve actuator/positioner operation and failure mode;
- Valve orientation,



- Plant Control and Monitoring System interface.

### 3.10.1 Metering

Accuracy Test by means of secondary injections.

### 3.10.2 Instrumentation

The tests and Pre-Commissioning shall be generally in accordance with IEC 62337 or equivalent. Test documents shall be produced and shall include checklists to be witnessed by the Employer. These tests documents shall contain agreed acceptance criteria.

The Contractor shall record the results of all calibration checks and loop tests on suitable check sheets such as those examples given in IEC 62337.

Pre-Commissioning will in general be achieved in the following stages:

- Calibration and performance tests prior to operation.

The site acceptance tests shall include but not limited to the following:

- Pre-Commissioning tests including, instrument calibration check to Plant Control and Monitoring System control loops, device drivers, protection and interlock logic, sequences, station master load control, alarms etc.
- Calibration of total loop.
- Performance check using simulated input/output conditions.
- Sequence and interlock equipment proving.
- Control loop functions using simulated conditions.
- Software testing with all nodes connected and functioning.

These shall be carried out with equipment connected to the main plant and shall as far as possibly demonstrate that plant may be controlled safely and to specification.

## 4. Commissioning

### 4.1 General

Commissioning of the Facilities shall be commenced by the Contractor immediately after issue of the Completion Certificate, in accordance with the General Conditions of Contract.

### 4.2 Materials and Tools

Measuring, testing and communication equipment and tools shall be made available by the Contractor.

### 4.3 Instruments

The same prescriptions as in clause 3.6 shall apply.

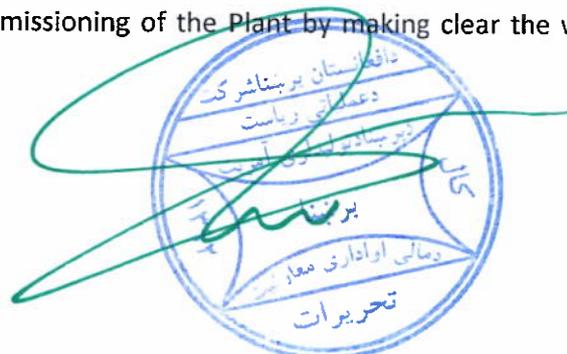
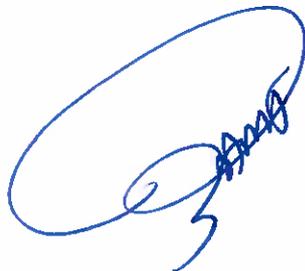
### 4.4 Commissioning Manuals

The Contractor shall prepare a "Commissioning Manual" to be submitted to the Employer for review. The commissioning instructions shall describe the commissioning procedures in sufficient detail to identify all the work steps and the prerequisites for the other associated plant and systems.

They shall be complete with sample check schedules and record sheets for each type of equipment item of the Plant, including instrumentation, control and electrical items.

The main purpose of the commissioning instructions shall be to:

- Facilitate the co-ordination of the commissioning of the Plant by making clear the work steps necessary;



- Identify possible restraints on the commissioning of the Plant supplied from equipment supplied under other contracts;
- Provide means of recording and monitoring the progress of commissioning work;
- Ensure that full records are made of the commissioning work and the condition of the items of the Plant when commissioned;
- Identify start-up procedures used to ensure safety of personnel and the Plant during the commissioning stages.

#### 4.5 Commissioning Plans

The Contractor shall prepare detailed Plant commissioning plans including critical path chart and associated Gantt chart. The commissioning plans shall include all activities that are to be completed by third parties so to enable the commissioning to proceed as planned.

The Contractor shall co-operate with the Employer and other involved parties to ensure practical coordinated plans are produced which include definition of the responsibilities of the various parties at the various stages of commissioning.

Commissioning in this sense includes all activities involved in putting the Plant into service.

#### 5. Training

The implementation of a structured training program for Employer's operation and maintenance employees in the following areas:

- Mechanical;
- Electrical;
- Instrumentation and control;
- Health and Safety; Constitutes a contractual obligation of the Contractor.
- On jobs training during replacement of unit 1
- Protection system
- Operation and maintenance
- Governor system
- Excitation system

##### 5.1 Basic Criteria

The training shall be implemented through two different types of courses, namely:

Overseas Courses to provide the personnel at managerial level, with the basic knowledge regarding the equipment, its technical characteristics and functionality, the organization and management of the power plant.

On Site Courses to prepare engineers, technicians and operators of Mahipar hydro power plant on all operational aspects such as:

- Equipment functionality;
- operation philosophy and interrelation between field and hydro power plant systems;
- maintenance (overhaul, predictive, preventive) and relevant procedures and actions);

With reference to maintenance activity, particular importance shall be given to the problem-solving approach and to the rules of the use of specific equipment and appliances.

The on-site courses shall be held both in English and Pashto/Dari languages. Training activities shall be coordinated by a training specialist who shall monitor the implementation of the training according to the program agreed.

All the trainees shall assist to the tests planned for the commissioning.



## 5.2 Training Program

### 5.2.1 Overseas Courses

#### Personnel Involved

The training course shall last at least four weeks and shall involve three trainees for each engineering discipline:

- Mechanical
- Electrical
- Instrumentation and supervision
- Project management and Health and Safety

The Contractor at the beginning of its activity shall prepare and submit to the Employer for approval a detailed training program articulated according to the indicative scheme described in details in the following paragraphs.

### 5.2.2 General Subjects

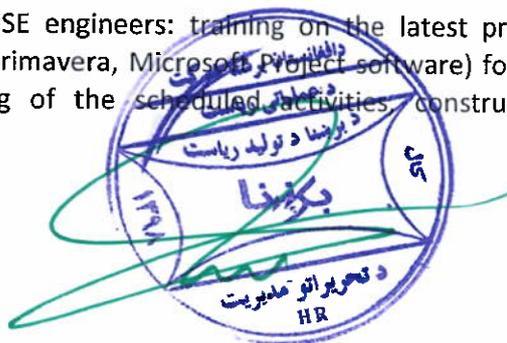
The first one week shall be devoted to lectures on subject related to general aspects of plant operation and maintenance such as:

- Organization of operation and maintenance in order to achieve the maximum efficiency and reliability of the Power Plant and to optimize the exploitation of the available resources.
- Power Plant (Powerhouse and Weir) operation and maintenance planning.
- Mechanical and electrical equipment characteristics and functions.
- Control and instrumentation (DCS) theory.
- HSE (Health Safety and Environment).
- All the trainees participating to overseas courses will attend these lectures.

### 5.2.3 Specific Subjects

During the last three weeks the trainees shall be divided into groups on the basis of their specific professional qualification to attend the courses on the following disciplines and the relevant specific topics specified below:

- Electrical, Mechanical: hydro generator operation and maintenance activity; gates maintenance, pump motor servicing; compressed air system servicing, etc.;
- Operator Engineer: major features of the DCS system, display process diagram graphics, evaluation point alarm conditions and acknowledge emergent alarms, creation live and historical trends, analyzing system problem conditions, interpretation and tuning implemented control using the available tools, etc. During the training particular attention shall be give on engineering and maintenance activities of DCS software (implementation or modification of control loop, sequential control, etc..) and on control philosophy of Mahipar Hydro Power Plant (Water Level Control, etc.....)
- Project Managers and HSE engineers: training on the latest project management tools (i.e. Primavera, Microsoft Project software) for the planning and monitoring of the scheduled activities construction



methodologies and procedures; quality control of construction site; technology of construction materials; environmental modelling, safety matters;

#### 5.2.4 Cost

The Contractor shall bear the costs for training and documentation for all trainees, in addition to the following items:

- air fare from/to Erbil for each of the trainees,
- Suitable accommodation for each of the trainees,
- Daily living allowance for each of the trainees.

#### 5.2.5 on Site Courses

##### Personnel Involved

The course shall last at least 5 weeks and shall involve about the engineers or technicians and operators assigned to plant operation and maintenance activities.

The Contractor at the beginning of its activity shall prepare and submit to the Employer for approval a detailed training program according to the tentative scheme indicated in details in the following paragraphs.

#### 5.2.6 Training Program

The program shall be articulated in two periods of three weeks and two weeks respectively:

- During the first period the courses, attended by all trainees, shall include:
  - Tools and instrumentation use for predictive maintenance.
  - Use of main tools for maintenance activities.
  - Electrical man oeuvres and procedure to change auxiliary service and to put in operation and to feed the Medium Voltage and Low Voltage auxiliary services board by means of the diesel generator; electrical protection function;
  - Firefighting system;
  - DCS hardware and software.
    - During the second period the trainees subdivided in the following groups will attend their courses according to the following scheme:
      - Operators and Engineers: - DCS operation;
  - procedure for Power Plant operation in all possible different conditions, such as starting operation, synchronous condenser operation, normal operation, black start operation, island operation etc.
  - procedures to put in safety conditions the equipment;
  - personal safety equipment;
  - Procedures and methods to minimize the unavailability; - Social and environmental monitoring.
    - Maintenance Personnel and Engineers:
      - Methods and instrumentation for physical measurements;
      - Methods and instrumentation for actuators valve calibration;
      - Gates maintenance;
      - Electrical protection;
      - Regulating devices;
      - Procedures to put in safety conditions the equipment;





Employer's Requirements for MHPP Rehabilitation, Replacement and Overhauling

1.14	Air piping and valves systems	02-1Ts714A-5891II
1.15	Water piping and valves	2.21-22143
1.16	Oil piping and valves systems	2.21-021429
1.17	Penstock MIV electric bypass	2.53-009519
1.18	Governing systems with all accessories	2.40-2137
1.19	Turbine cooling water supply systems with all accessories	2.21-021445
1.20	Turbine oil cooling systems with all accessories	L 282.00.2200
1.21	Turbine air compressing systems with all accessories	79944-S 03-151299
1.22	Turbine Shafts	2.21-021628
1.23	Spiral case	2.55-10951
1.24	Draft tube	
1.25	Tailrace stop logs	2.51-007320
1.26	Stop logs of diversion dam	01-32-406-1501
1.27	Main inlet valve	2.41-022166
1.28	Gate valve control	2.41-022156
1.29	Oil pressure systems of gate valve	2.41-021595
1.30	Gate valve operating systems	2.40-012142
1.31	Gate valve control systems	2.41-022173
1.32	Main control valve to the KUGLESCHIEBERS	2.53-009504
1.33	Maintenance seals and control system	2.41-022167
<b>2</b>	<b>Generator</b>	
2.1	Three phase synchronous generator with all accessories	10.00 Generator folder
2.2	Lower bearing with hub	OD 2363-139098
2.3	Upper bearing with hub	OD 2061-139810
2.4	Thrust bearing with hub	OD 2360-139093
2.5	Shaft	2.21-021458



Employer's Requirements for MHPP Rehabilitation, Replacement and Overhauling

2.6	Generator cooling systems with all accessories	1D 2363-139100
2.7	Oil cooling systems with all accessories	OD 2388-139118
2.8	Brake systems	OD2180-65172
2.9	Generator oil 15T systems	
2.10	7 bar systems with all accessories	OD2381139116
2.11	Water cooling systems with all accessories	
2.12	Water piping and valve systems	A23795
2.13	Oil piping and valve systems	OD2388-139118
2.14	Air piping and valve systems	
2.15	Excitation systems with all accessories	1D2389-139120
2.16	Bus bars	OTS714-6337
2.17	Upper spider	OD2389-139122
2.18	Lower spider	OD2352-139085