

# STANDARDS/MANUALS/ GUIDE LINES FOR SMALL HYDRO DEVELOPMENT

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## **3.6 Electro-Mechanical– Technical Specifications for Procurement of Generating Equipment**

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Sponsor:

Ministry of New and Renewable Energy  
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Lead Organization:

Alternate Hydro Energy Center  
Indian Institute of Technology Roorkee

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The constraints of time and resources available to this nature of assignment, however do not preclude the possibility of errors, omissions etc. in the data and consequently in the report preparation.

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*AHEC-IITR, "3.6 Electro-Mechanical – Technical specification for procurement of generating equipment", standard/manual/guideline with support from Ministry of New and Renewable Energy, Roorkee, November 2012.*

## **PREAMBLE**

There are series of standards, guidelines and manuals on electrical, electromechanical aspects of moving machines and hydro power from Bureau of Indian Standards (BIS), Rural Electrification Corporation Ltd (REC), Central Electricity Authority (CEA), Central Board of Irrigation & Power (CBIP), International Electromechanical Commission (IEC), International Electrical and Electronics Engineers (IEEE), American Society of Mechanical Engineers (ASME) and others. Most of these have been developed keeping in view the large water resources/ hydropower projects. Use of the standards/guidelines/manuals is voluntary at the moment. Small scale hydropower projects are to be developed in a cost effective manner with quality and reliability. Therefore a need to develop and make available the standards and guidelines specifically developed for small scale projects was felt.

Alternate Hydro Energy Centre, Indian Institute of Technology, Roorkee initiated an exercise of developing series of standards/guidelines/manuals specifically for small scale hydropower projects with the sponsorship of Ministry of New and Renewable Energy, Government of India in 2006. The available relevant standards / guidelines / manuals were revisited to adapt suitably for small scale hydro projects. These have been prepared by the experts in respective fields. Wide consultations were held with all stake holders covering government agencies, government and private developers, equipment manufacturers, consultants, financial institutions, regulators and others through web, mail and meetings. After taking into consideration the comments received and discussions held with the lead experts, the series of standards/guidelines/manuals are prepared and presented in this publication.

The experts have drawn some text and figures from existing standards, manuals, publications and reports. Attempts have been made to give suitable reference and credit. However, the possibility of some omission due to oversight cannot be ruled out. These can be incorporated in our subsequent editions.

This series of standards / manuals / guidelines are the first edition. We request users to send their views / comments on the contents and utilization to enable us to review for further upgradation.

Standards/ Manuals/Guidelines series for Small Hydropower Development

<b>General</b>	
1.1	Small hydropower definitions and glossary of terms, list and scope of different Indian and international standards/guidelines/manuals
1.2 Part I	Planning of the projects on existing dams, Barrages, Weirs
1.2 Part II	Planning of the Projects on Canal falls and Lock Structures.
1.2 Part III	Planning of the Run-of-River Projects
1.3	Project hydrology and installed capacity
1.4	Reports preparation: reconnaissance, pre-feasibility, feasibility, detailed project report, as built report
1.5	Project cost estimation
1.6	Economic & Financial Analysis and Tariff Determination
1.7	Model Contract for Execution and Supplies of Civil and E&M Works
1.8	Project Management of Small Hydroelectric Projects
1.9	Environment Impact Assessment
1.10	Performance evaluation of Small Hydro Power plants
1.11	Renovation, modernization and uprating
1.12	Site Investigations
<b>Civil works</b>	
2.1	Layouts of SHP projects
2.2	Hydraulic design
2.3	Structural design
2.4	Maintenance of civil works (including hydro-mechanical)
2.5	Technical specifications for Hydro Mechanical Works
<b>Electro Mechanical works</b>	
3.1	Selection of Turbine and Governing System
3.2	Selection of Generators and Excitation Systems
3.3	Design of Switchyard and Selection of Equipment, Main SLD and Layout
3.4	Monitoring, control, protection and automation
3.5	Design of Auxiliary Systems and Selection of Equipments
3.6	Technical Specifications for Procurement of Generating Equipment
3.7	Technical Specifications for Procurement of Auxiliaries
3.8	Technical Specifications for Procurement and Installation of Switchyard Equipment
3.9	Technical Specifications for monitoring, control and protection
3.10	Power Evacuation and Inter connection with Grid
3.11	operation and maintenance of power plant
3.12	Erection Testing and Commissioning

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# TECHNICAL SPECIFICATIONS FOR PROCURMENT OF GENERATING EQUIPMENT

## 1.0 GENERAL

### 1.1 Scope

The scope of this guide line is to provide guidance for preparation of technical specification of generating equipment for procurement of the same. This includes, scope, design conditions, performance guarantee, general arrangement and constructional feature, shop assembly & tests, site installation testing and commissioning of different type of hydraulic turbines and commissioning of different type of hydraulic turbines, and generators, as also other relevant information. For covering all type of Hydro turbines and hydro generators being used these days in small hydro power plants, the guide lines have been sub divided in following main sequence:

- (1) General technical specification for electro-mechanical works
- (2) Technical specification for Francis Turbine
- (3) Technical specification for Kaplan Turbine
- (4) Technical specification for Pelton and Cross Flow Turbine
- (5) Technical specification for Tubular / Bulb Turbine and speed increaser
- (6) Technical specification for governing system
- (7) Technical specification for Synchronous Generator, AVR & Excitation system
- (8) Technical specification for Induction Generator
- (9) Technical specification for Main Inlet Valves
- (10) Guaranteed Technical Particulars

### 1.2 References

Following National and International codes and standards shall be referred in preparation of technical specifications for various generating equipments:

R1	IEC:60041-1991	Field acceptance tests to determine the hydraulic performance of hydraulic-turbines, storage pumps and pump turbines
R2	IEC:60193-1999	Hydraulic turbines, storage pumps and pump turbine model acceptance tests
R3	IEC:60308-2005	Hydraulic turbine- testing of control systems
R4	IEC:60609-1997	Cavitation, pitting evaluation in hydraulic turbine, storage pumps and pump turbines
R5	IEC:61125-1996	Recommended practice for preparation of equipment specifications for speed governing of hydraulic turbines intended to drive electric generators
R6	IEC 60034-11-2004	Rotating electrical machines
R7	IEC 60034-18-32-2010	Functional evaluation of insulation system test procedures for form – wound windings – evaluation by electrical endurance
R7	IEC 60034-2010	Direct action indicating electrical measuring instruments
R8	IEC 60055-2005-Part 2	Paper-insulated metal-sheathed cables for rated voltages up to 18/30 kV

R9	IEC 62271.100-2008-Part 100	High voltage switch gear and controls -Alternating current circuit breakers
R10	IEC 60068-2008-Part 2-27	Environmental testing Tests – Test Eq. and guidance shock
R11	IEC 60071-2011-Part1	Insulation co-ordination
R12	IEC 60072-1994	Dimensions and output ratings for rotating electrical machines
R13	IEC 60073-2002	Basic and safety principals for man machine interface marking and identification coding principles for indicators and actuators
R14	IEC 60076-2008 Part 12	Power Transformers
R15	IEC 60085-2007	Electrical insulation – Thermal evaluation and designation
R16	IEC 60086-2011	Primary Batteries
R17	IEC 60095-2009-Part 2	Lead Acid Starter Batteries
R18	IEC 60099-2009-Part4	Surge arresters
R19	IEC 62271-2012-Part 102	High voltage switch gear and controls
R20	IEC60 137-2008	Insulated bushings for alternating voltages above 1000 V.
R21	IEC 60947.1-2011	Low voltage switch gear and control gear- part1
R22	IEC 60947 -2009-Part 2	Low voltage switchgear and control gear -2
R23	IEC 60168-2000	Tests on indoor and outdoor post insulators of ceramic material or glass for systems with nominal voltages greater than 1000 V
R24	IEC 60044-1-2000	Current transformers
R25	IEC 60044-2-2003	Inductive voltage transformers
R26	IEC 60189-2007-Part 3	Low frequency cables and wires with P.V.C. insulation and PVC sheath
R27	IEC 60214-2003-Part 1	Performance requirements and test methods
R28	IEC 60227-2012- Part 7	Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V.
R29	IEC 60228-2004	Conductors for insulated cables
R30	IEC 60230-1966	Impulse tests on cables and their accessories
R31	IEC 60255-2010-Part 27	Measuring relays and protection equipment
R32	IEC 60287-2006-Part 2	Electrical cables calculation of current rating
R33	IEC 60947.4.3-2012	Low voltage switch gear and control gear
R34	IEC 60296-2012	Fluids for electro-technical applications
R35	IEC 62271.200-2011	High voltage control gear and switch gear
R36	IEC 60304-1982	Standard colours for insulation for low frequency cables and wires
R37	IEC 60344-2007	Guide to the calculation of resistance of plain and coated copper conductors of low-frequency cables and wires.
R38	IEC60 076.7-2005	Loading Guide for oil immersed transformers
R39	IEC602271.101-2010	Report on synthetic testing of high voltage alternating current breakers.
R40	IEC 60439-2006-Part 5	Low voltage switchgear and control gear assemblies
R41	IEC60 446-2007	Identification of insulated and bare conductors by colours
R42	IEC 60447-2004	Basic and safety principles for man machine interface, making and identification
R43	IEC 60489-2000	Methods of measurement of radio equipment used in the mobiles services

R44	IEC 60502-2009	Extruded solid dielectric insulated power cables for rated voltages from 1 kV up to 30 kV
R45	IEC 62052.21-2004	Electricity metering equipment (a.c.)
R46	IEC 61366 – 1998-Part 1	General and annexures
R47	IEC 61366 – 1998-Part 2	Guidelines for technical specifications for Francis turbines
R48	IEC 61366 – 1998-Part 3	Guidelines for technical specifications for Pelton turbines
R49	IEC 61366 – 1998-Part 4	Guidelines for technical specifications for Kaplan and Propeller turbines
R50	IEC 61366 – 1998-Part 5	Guidelines for technical specifications for Tubular turbines
R51	IEC 60811.1-1 -2001	Test methods for insulations and sheaths of electric cables and cords
R52	IEC-61116-1992	Electromechanical Equipment Guide for Small hydroelectric Installations
R53	IEEE 115-2009	Test Procedure for Synchronous Machine
R54	ASME Power Test Codes-1949	Test code for Hydraulic Prime Movers
R55	IS:12800(Part-3) -1991	Guidelines for Selection of Hydraulic Turbine, Preliminary Dimensioning and Layout of surface hydroelectric Powerhouses Part 3 Small, Mini And -Micro -Hydroelectric Power Houses
R56	IS:4722-2001	Rotating electrical machines - specification
R57	IS:325-2007	Three phase induction motors
R58	IS:8789-2007	Values of performance for three-phase induction motors
R59	IS:3156-2002	Voltage transformers
R60	IS:L3156(Pt.I)-2002	General requirements
R61	IS:3156(Pt.II)-2002	Measuring voltage transformers
R62	IS:3156(Pt.III)-2002	Protective voltage transformer
R63	IS:3156(Pt.IV)-2002	Capacitor voltage transformers
R64	IS:2705-2007	Current transformers
R65	IS:2705(Pt.I)-2002	General requirements
R66	IS:2705(Pt.II)-2002	Measuring current transformers
R67	IS:2705(Pt.III)-2002	Protective current transformer
R68	IS:2704(Pt.IV)-2002	Protective current transformers for special purpose applications
R69	IS:2026-2006	Power transformers
R70	IS:2026(Pt.I)-2006	General
R71	IS:2026(Pt.II)-2006	Temperature-rise
R72	IS:2026(Pt.III)-2006	Insulation levels and dielectric tests
R73	IS:2026(Pt.IV)-2006	Terminal markings, tappings and connection
R74	IS:335-2005	New insulating oils
R75	IS:3231-2009	Electrical relays for power system protections
R76	IS:3043-2006	Code of practice for earthing
R77	IS:1651-2007	Stationary cells and batteries lead-acid type (with tubular positive plates)
R78	IS:13118-2007	Specification for high voltage alternating – current circuit breakers
R79	IS:13947-2004-Part 1	Specification for low voltage switchgear and control gear
R80	IS:L1554(Pt.II)-2005	Specification for PVC insulated electric cables

R81 IS:5613(Pt.I/Sec.I) 2007 Code of practice for design, installation and machine of over head power lines

## **ABBREVIATIONS**

ASME : American Society of Mechanical Engineers  
IEC : International Electro technical Commission  
IEEE : Institute of Electrical and Electronic Engineers  
IS : Indian Standards from Bureau of Indian Standards

## **2.0 TECHNICAL SPECIFICATIONS FOR ELECTRO-MECHANICAL WORKS**

The Contractor shall strictly observe these General Technical Specifications in conjunction with the Particular Technical Specifications for various elements of E & M works. He shall carry out all work in a skilled and workman like manner in compliance with modern methods of engineering. All design, calculations, materials, works, manufacturing process and testing shall conform to the latest applicable Standards.

Whenever a Bidder deviates from these Specifications, he shall furnish the data called for in the Technical Data Schedules and give a summary of and the reasons for all deviations in the "**List of Deviations**". Failure to accomplish this, may cause the elimination of his Tender, especially when a major deviation is involved.

In addition, the Contractor shall conform to all applicable regulations regarding the execution of construction and installation work, and shall follow all instructions issued by the competent Authorities, and the Engineer.

### **2.1 Scope of Work**

The scope of work in this part of Contract is established in the Particular Technical Specifications for various elements of E & M works. The Contractor shall design, manufacture, supply, erect, test & commission and hand-over to Owner and guarantee for 18 months after commissioning and handing over of all works complete in every respect with all necessary accessories for reliable continuous operation as per the detailed particular technical specifications.

These Specifications include the performance of all works and the provision of all labours, materials, permanent and temporary equipment, tools, accessories for transport to the site, including loading, unloading, if necessary reloading in the port of arrival, complete installation, painting, testing and commissioning of all works and accessories of E&M works.

The Contractor shall make competent and experienced staff available for the training and assistance of the operating staff during commissioning and trial operation and, if required by the Owner, for a period after completion of the trial operation which shall be agreed separately.

### **2.2 Standards**

All equipment supplied/works executed under this Specification shall conform to the latest editions together with any Amendments issued to that date. If requested by the

Engineer, the Contractor shall supply at his own expense two copies in English of any national standards, which are applicable to the Contract. Standard publications issued by the following organisations of standardisation are considered being approved standards for the works:

### **Standards for General Application**

AISI	:	American Iron and Steel Institute
ANSI	:	American National Standards Institute
ASME	:	American Society of Mechanical Engineers
ASTM	:	American Society for Testing and Materials
AWS	:	American Welding Society
BS	:	British Standards
CMAA	:	Crane Manufacturers Association of America
DIN	:	Deutsche Institute für Normung
IEC	:	International Electro technical Commission
IEEE	:	Institute of Electrical and Electronic Engineers
IPCEA	:	Insulated Power Cable Engineer's Association
IS	:	Indian Standards
ISO	:	International Standards Organisation
JEC	:	Standards of the Japanese Electro technical Committee
JIS	:	Japan Industrial Standards
NEMA	:	National Electrical Manufacturers Association
VDE	:	Verein Deutscher Elektroingenieure
VDI	:	Verein Deutscher Ingenieure

"Notwithstanding reference made to various standards all equipment and works as per provisions and requirements of relevant and latest Indian Standards shall be acceptable".

In the case of equipment offered from a country where the relevant standards to which the equipment conforms are in the opinion of the Engineer equal to or better than I.E.C., these are acceptable, but appropriate standards shall be quoted at the time to tender. Full details of differences, which affect the design or performance of the equipment, shall be stated in the tender and English translations of any such alternative standards shall be supplied by the Contractor when requested by the Engineer.

### **2.3 Designs for Climate, Earthquake Etc.**

All outdoor equipment supplied shall be suitable for operating under the worst tropical conditions, including lightning, cyclonic rains, and high humidity. All equipment shall be adequately protected against ingress of dust, vermin, moisture and tropic proofed in an approved manner.

The generating equipment and associated electrical equipment shall be designed to withstand loads due to earthquakes in accordance with Indian Standards.

### **2.4 Design Coordination Meeting**

The Contractor will be called upon to attend design coordination meetings with the Engineer and the Consultants of the Owner during the period of Contract. The Contractor shall attend such meetings at his own cost at mutually agreed venue as and when required and fully cooperate with such persons on agenda involved during discussions.

## **2.5 Technical Documents**

### **2.5.1 General**

This Chapter specifies the general scope of the documents which, together with those listed in the Particular Specifications, shall be delivered by the Contractor to the Engineer within the periods, and in a number and quality as specified in the General Contract Conditions and Special Contract Conditions .

The Engineer reserves the right to request the Contractor for additional documents as may be required for proper understanding and definition of constructional, operational, co-ordination or other matters.

All documents to be supplied shall be submitted in accordance with the agreed programme so that any comment and change requested by the Engineer can be taken into account before starting of the manufacture in the workshop and / or erection at the site. The Contractor shall not be relieved of his responsibility and guarantee after drawings and computations have been approved by the Engineer.

### **2.5.2 Drawings**

Drawings in respect of the following shall be supplied in hard and soft copies:

#### **i) Foundation Drawings**

If a piece of Works requires its own foundation or needs a special area for installation, the Contractor shall submit drawings indicating all pertinent dimensions, static and dynamic loads, etc. They shall include all essential details required for proper design and construction of the foundations and/or buildings.

In addition, they shall include openings, sleeves, and details of conduits, slopes and the arrangement of any supporting structure, i.e. base-frames or other steel constructions for permanent fixing or erection purposes.

#### **ii) Arrangement and Layout Drawings**

All arrangement and layout drawings shall be drawn to scale. The General Arrangement Drawings shall show the physical arrangement of Works and their layout in the Power House, switchyard and appurtenances.

#### **iii) Assembly and sub-Assembly Drawings**

The assembly drawings shall show all elements and the main dimensions of individual components in plan view, cross-section, side and top views. The **assembly** drawings shall include erection drawings, piping diagrams and piping arrangement drawings, etc., showing the dimensions, design and data of all constructions, apparatus and Works to be furnished under this Contract.

These drawings shall show:

- Assembly of the Works in plan, elevation and detail views with main dimensions
- Sub-assembly of the principal components of the Works which shall require dismantling, assembly and adjustments at site for maintenance, giving overall dimensions, adjustment, clearances and fitting tolerances
- Sub-assemblies in which the Contractor proposes to ship the Works
- Instructions for heat treatment, pressure tests, surface preparation and anti-corrosive protection
- Full details of parts for which adjustment is provided or which are subject to wear
- Method and sequence of installation, field joints, erection and lifting devices, jacks, grout plugs, anchoring details, etc., if not shown on foundation drawings.

**iv) Schematic Diagrams**

Schematic diagrams of turbine control and auxiliary systems like oil pressure unit, compressed air system, drainage / dewatering system, cooling water system etc. shall be supplied. These drawings shall show all instruments and control devices. Standard abbreviations and component numbers shall be used as per relevant standards.

**v) Single-Line Diagrams**

Each electrical works and their circuits shall be represented by a single line diagrams. It shall contain all required technical information of the Works represented, e.g. voltage, current, capacity, short-circuit level, ratios, voltage variations, instrument transformer and protection relay indices, interlocking, kind of switch drive, code designation, etc. as applicable.

Single-line diagrams of individual main components and switchboards shall additionally show the control, indicating, metering, protection, automatic controlm, and other auxiliary electric devices separated for each individual installations item and location as applicable:

**vi) Circuit Diagrams**

The Circuit Diagrams shall show the power circuits in all phases with the main apparatus as well as the pilot circuits (measuring and control circuits). It shall show in full the functioning of part or all installations, Works or circuits with all required technical information.

The control part shall be subdivided into separately drawn "current paths", each showing all its components regardless of their actual physical location. The individual circuits are to be drawn in a straight-line sequence, avoiding line crossings. The current paths (to be designated by numbers) shall be drawn starting from two horizontal lines, which represent the control voltage source. All devices belonging to the Works or forming part of the Works or control devices shall appear between these two lines.

Contact developments of the installed switches, contactors, relays and other apparatus which appear in the diagram shall be shown below the respective contactor coil, indicating by means of numbers and, if not on the same, also the page No., the current path in which the corresponding contact has been used.

Circuit diagrams shall also contain all terminals and their correct designations. Terminals grouped together to terminal blocks of switchboards, distributors, etc.

The representation of electrical Works and control circuits shall not be terminated at the limits of the scope of supply, but has to be extended beyond this limit by all switchgear, protective, measuring and monitoring equipment required for full comprehension of the whole circuit. All terminals and functions of Works to be supplied by others shall be taken over as well.

#### **vii) Block Diagrams**

The Block Diagrams shall be used to show in a simplified manner the main inter-relationships between the elements of a system by means of symbols, block symbols and pictures without necessarily showing all the connections. The symbols used for the individual kinds of components, e.g. servomotors, computing modules, etc., shall clearly be explained on the diagram or on an attached legend.

#### **viii) Logic Diagrams**

The Logic or Functional Diagrams shall be used for representation of logic and sequence controls and inter locking by showing only binary logic elements and their effect on the various process equipment disregarding their electrical realisation. Logic function elements (AND, OR, NOR, NAND, STORAGE, etc.) shall be used for processing and combining binary signals.

#### **ix) Terminal Diagrams**

Such diagrams shall be prepared for any type of terminal box, marshalling rack, control cubicle, switchboard, etc., and shall show the terminals (properly numbered) and the internal and/or external conductors (wires or cables) connected to them. The terminal diagram of each individual switchboard, terminal box, panel, etc., shall contain, but not be limited to the following information:

Terminal number of terminal board with targets (terminal number and current path) of incoming and outgoing cables and wires

- Cable designation
- Type of cable
- Number and cross-section of conductors

### **2.5.3 Lists and schedules**

Following lists and schedules shall be supplied:

**i) Cable Lists / Interconnection Lists**

The Cable Lists shall include for each individual cable the following as a minimum:

- Cable number, in accordance with Identification System.
- Cable type
- Rated voltage
- Number and size of conductors
- Overall diameter
- Cable termination at each end
- Connection point at each end with cubicle/Works identification and terminal numbers
- Cable routing

In case interconnecting cubicles are used, the lists shall be prepared to show:

- Cable termination for incoming and out coming cables
- Interconnection wiring

**ii) Alarm Lists**

These lists shall indicate all alarms and shall contain at least:

- Description and denomination of alarm
- Data of alarm detector (contact) referring to applicable circuit diagram
- Data of alarm annunciator (location and clear text labelling)

**iii) List of Final Control Elements**

This list shall indicate all control actuators and control valves and shall contain at least:

- Data of pipe and valve connections
- Data of valve layout
- Maximal required and rated power

**2.5.4 Calculations**

In addition to the drawings or whenever the contractual documents do so require, the Contractor shall submit to the Engineer for checking, the appropriate calculations for determining the main sizes, stress levels, dimensions and operational characteristics, safety factors, clearly indicating the principles on which the calculations were based. The calculations shall include the formulae, standards, test results, basic assumptions, etc. Submission of computer calculations without baseline information such as derivation of the calculation method, applied formulas, definition of variables and constants, explanation of abbreviations etc., will not be accepted.

**2.5.5 Short-circuit calculations**

The short-circuit calculations shall be performed in accordance with VDE Standard 0102- part I / IEEE 242-2001 and 399-1997.

### 2.5.6 Operation and maintenance manuals

The Operation and Maintenance Manuals shall be prepared in latest version of MS Word with enclosures in the form of computerised drawings and scanned figures. They shall be supplied on 2 DVD along with Three (3) hard copies in properly bound form. The O & M manuals shall contain the following information in sufficient detail to enable the Owner to maintain, dismantle, reassemble, adjust and operate the Works with all its items of Works and installations:

- a) Table of Contents
- b) List of Illustrations
- c) Introduction
- d) Detailed Description: Detailed description shall contain a complete and accurate description of the Works, all components and ancillaries, their assembling and dismantling. An accurate list stating clearances, tolerances, temperatures, fits, etc. shall be included.
- e) Operating Principles and Characteristics: A brief summary of the technical operating principles of the Works, including diagrams, circuit diagrams, sequence diagrams, piping, etc.
- f) Operating Instructions: The instructions shall contain the sequence of individual manipulations required for operation. Tables, lists and graphic presentations should be used whenever possible for making the description readily understandable. An appropriate trouble-shooting list shall be included in this chapter.
- g) Testing and Adjustment: The entire testing and adjustment procedure required for the Works after overhauls and during operation shall be described.
- h) Maintenance Instructions: This section is divided into five paragraphs:
  - Preventive maintenance, indicating the inspections required at regular intervals, the routine cleaning and lubricating operations, the regular safety checks and similar steps. The maintenance instructions shall include a tabular summary of the required activities sorted according to Daily, Weekly, Monthly, Quarterly, Yearly, (Or other) cycles as applicable.
  - Repair and adjustment procedures including fault tracing
  - Spare part lists, containing all the necessary data for ordering spare parts. These lists shall include all spare parts, those to be supplied and those not to be supplied under the present Contract. *Detailed drawing for each item of spare parts shall be supplied.* The above list should include minimum and maximum quantities of spares to be maintained by the project.
  - Tool lists, containing all necessary data for identification of tools to be delivered under the present Contract.
  - List of Contractors of bought out items and their addresses.
- i) As-built drawings

### 2.5.7 Installation and commissioning manuals

The Manuals of Installation and Commissioning Procedures shall be prepared in latest version of MS Word with enclosures in the form of computerised drawings and scanned figures. They shall be supplied on 2 DVD along with 3 (Three) hard copies in properly bound form. These manuals shall contain the following information in detail:

- a) **Installation Procedures:** The installations procedures shall describe in sequential steps the erection of major equipment and shall contain sufficient details such as equipment preparation on erection bay, handling of large and heavy pieces, levelling, anchoring, site welding, site painting, erection checks, site pressure tests, site flushing and cleaning of hydraulic systems, alignment and run out checks to allow the Engineer / Owner to plan and supervise the Works at site, if required. The manuals shall contain the Log Sheets for taking measurements during installation.
- b) **Pre-Commissioning Tests and Procedures:** Pre-commissioning tests and procedures shall be described in sequential steps for the pre-commissioning of all electrical and mechanical equipments and shall also contain sufficient details viz. checking of installations, ratings, cable terminal checking and operation test of all auxiliary equipments etc. necessary Log Sheets shall be annexed to facilitate proper recording of test results.
- c) **Commissioning Procedures:** The commissioning procedures shall sequentially and in sufficient detail describe activities and tests for all systems covered by these specifications.

#### **2.5.8 Progress reports during design and manufacturing**

During design and manufacturing the Contractor shall quarterly submit two (2) copies of the progress reports with one CD in a format acceptable to the Engineer, detailing the progress of the work during the preceding period. The report shall contain (but not be limited to) the following information:

- A general description of the Works performed during the reporting period on each main activity, and include any notable problems, which were encountered.
- The total overall percentages of design and manufacturing works completed, with reference to the CPM programme. Appropriate comments shall explain any differences.
- The percentages of each main work activity completed during the reported quarter with reference versus the scheduled programme. Appropriate comments shall explain any differences.
- A list of activities scheduled to be started within the next period of two (2) months, with expected starting and completion dates. If the expected starting and/or completion dates are different from those shown on the CPM programme, an explanation shall be given.

#### **2.5.9 Progress reports during installation at site**

During erection the Contractor shall, before the tenth (10th) day of each calendar month, submit Two (2) copies with one CD of the monthly progress reports in a format acceptable to the Engineer, detailing the progress of the work during the preceding month. The report shall contain (but not be limited to) the following information:

- A general description of the Works performed during the reporting period on each main activity, and include any notable problems, which were encountered.

- The total overall percentages of erection works completed, with reference to the CPM programme. Appropriate comments shall explain any differences.
- The percentages of each main work activity completed during the reported month with reference versus the scheduled programme. Appropriate comments shall explain any differences.
- A list of activities scheduled to be started within the next period of two (2) months, with expected starting and completion dates. If the expected starting and/or completion dates are different from those shown on the CPM programme, an explanation shall be given.
- A list of local manpower (by trade classification) employed during the reporting period.
- A list of expatriate personnel (by position) employed during the reporting period.
- A list of the Contractor's Equipment and materials presently located at the Site.
- Progress photographs of significant events. The Engineer may direct the inclusion of specific photographs if deemed necessary.
- A statement detailing the status of progress on the overall programme and how to regain any lost time or setbacks which may have occurred.
- A list of inoperable temporary equipment, and the estimated date when the repair will be completed.
- A statement concerning potential problems and recommendations on how they could be resolved.

#### **2.5.10 Quality assurance plan for manufacturing works**

Two copies of Quality Assurance Plan with one CD giving details of inspection, tests and customer witness / hold points shall be submitted with the bids. The quality plan shall contain the details of inspection and tests to be carried out for each major component of each functional assembly as recommended by the manufacturer as per their standard practice. The tests will include material composition and its properties, NDT, X-ray, hydraulic tests, leakage tests, insulation, high voltage tests and functional tests etc. along with the applicable standards and acceptance criteria.

The Contractor shall get the quality plans finalised and approved after the award of the Contract. The approved quality plan shall form the basis for inspection and acceptance of the equipment. The Engineer shall have the right to ask for more relevant tests if the same could not be included in the quality assurance plan at the time of their approval due to non availability of final design drawings.

#### **2.5.11 Quality assurance plan for site installation & commissioning**

Two copies of Quality Assurance Plan giving details of stage inspection during installation, pre-commissioning and commissioning tests and customer witness / hold points shall be submitted with the bids. The quality plan shall contain the details of inspection and tests to be carried out for each major component of each functional assembly as recommended by the manufacturer as per their standard practice. Test Procedure shall be specified giving for each test item (kind of test) a description, test method / standards, used instruments, sample/routine test, test judgement.

The tests will necessarily include NDT, X-ray, hydraulic tests, leakage tests, insulation, high voltage tests and functional tests etc. along with the applicable standards and acceptance criteria.

The Contractor shall get the quality plans finalised and approved after the award of the Contract. The approved quality plan shall form the basis for inspection and acceptance of the equipment at site. The Engineer shall have the right to ask for more relevant tests if the same could not be included in the quality assurance plan at the time of their approval due to oversight and/or non availability of final design drawings.

## **2.6 Spare Parts, Tools and Site Consumables**

### **2.6.1 Spare parts**

All spare parts to be supplied shall be interchangeable with the corresponding parts of all the Works supplied under these Specifications and shall be of the same material and workmanship. They shall be replaceable without cutting or destruction of adjacent components. All spare parts shall be protected against corrosion and shall be marked with identification labels. The identification scheme for spares shall be sent for Owner's approval before dispatch of any spare.

All spare parts, tools and materials shall be delivered in marked boxes of sufficient sturdy construction to withstand long term storage.

The required list of spare parts has been given in Technical Specifications of respective equipment/works. The Bidders will give a separate list of spares recommend by them in addition to the list given in particular specifications and offer the price of the same separately in schedule of prices for spares. Wherever the quantity of spares is given as set/sets, it will be taken as quantity for both generating units. Sufficient quantity of spares will be included for parts which are more prone to frequent wear and tear and can be replaced easily without involving long shutdown.

The Contractor shall provide 5%, but at least two pieces of all types of bolts, screws, nuts, washers, spanner rings and cotters. The quantity may be taken from the surplus handed over to the Owner after completion of the installation as described under the chapter "Bolts, Screws, Nuts, etc." of this Section.

Orders for recommended spare parts shall be optional to purchase by the Purchaser for a period of one (1) year after the date of the completion of the project.

### **2.6.2 Tools and appliances**

The scope of work shall include all customary and special tools, as well as auxiliary devices including lifting devices, ropes, etc. necessary for total assembly and disassembly of all parts of the supplied Works. Furthermore, all accessories for maintenance shall be supplied and included in the Tender. The total price for tools and devices as required by this article shall be included in the Total Tender Price. The special lifting devices and tools designed and supplied for the project, can be used by the Contractor during erection and will be handed over to Owner in good working condition without any wear and tear. However, ropes, slings, small hoists and winches etc. shall be handed over in new condition.

All lifting devices and wire ropes slings to be used at site shall be tested at works and test certificate shall be supplied to the Engineer.

Suitable tool boxes shall also be included in the delivery. An itemised list and description of all provided tools, auxiliary devices, etc. shall be included in the Tender. The Owner shall be entitled to take over from the Contractor the entire erection tools, appliances, instruments at mutually agreed conditions.

The scope of work shall include suitable numbers (to be specified by Purchaser) dual core, computer sets each with CD/DVD drive and multi-media facility, 21" LCD colour monitor, suitable UPS, external modems, A3 size laser printer with scanner.

### **2.6.3 Site consumables, lubricating oil and grease for first filling**

Scope of work shall include all site consumables like welding electrodes, brazing materials, insulating materials, sealants, cleaning agents, paints and varnishes, grinding wheels/discs, fasteners and raw materials etc. in fairly sufficient quantity so that erection and commissioning activity is not held up for want of these items.

For all items under this Contract, the Contractor shall deliver 5 % of the quantity of painting material, but at least one litre, in new sealed containers, for later repair works other than the Contractor's.

Lubricating oils, insulating oils and greases etc. required for first filling in the plant and equipment supplied by the Contractor under this Contract shall be supplied in quantity 20 % (twenty percent) higher than the actual capacity for first filling. These items shall be supplied as per site requirement and shall not be stocked with main equipment.

## **2.7 Design Requirements**

### **2.7.1 General**

The equipment shall be designed and manufactured to provide most optimum functional value and neat appearance. All major assemblies or equipment shall be designed to facilitate easy and quick surveillance, maintenance and optimum operation. All control sequences shall be simple and rational.

All live, moving and rotating parts shall be adequately secured in order to avoid danger to the operating staff. All electrical components shall be electrically earthed.

Suitable lifting eyes and forcing off bolts shall be provided where required or where they will be useful for erection and dismantling.

Any changes of the design of any part of the equipment, which may become necessary after signing the Contract have to be submitted in writing to the Engineer for approval, being sufficiently substantiated and justified.

Additional cost can only be accepted after mutual discussion; in case of a basic design the Engineer suggests change after award of Contract.

## 2.7.2 Design responsibility

The contractor shall assume full responsibility for a coordinated and adequate design of all equipment specified and shall ensure that such equipment conforms to the best engineering practice for the operating conditions specified. When requested by the Engineer, the Contractor shall furnish complete information as to the maximum stress and other criteria used in the design.

## 2.7.3 Working stress

Conservative factors of safety shall be used throughout the design and especially in the designs of all parts subject-alternating stresses of shock. For the rotating parts of the generator and exciters, the maximum units stresses due to runaway speed of turbine shall not exceed two –thirds of the yield point.

Maximum Unit Stresses in Kilogram per square Centimeter

<b>Material</b>	<b>Stress in Tension</b>	<b>Stresses in Compression</b>
Cast Iron	140	700
Cast Steel	700	700
Alloy Cast Steel	20 % of the ultimate Strength or 33 % of the yield point, whichever is less	20 % of the ultimate Strength or 33 % of the yield point, whichever is less
Plate Steel for Principal parts	840	840

For other materials used in the manufacture of the generator and exciter etc. the maximum stresses due to the most severe operating conditions shall not exceed one-third of the yield point nor one-fifth of the ultimate strength of the material. For temporary overloads, unit stresses not exceeding one-half the yield point stress will be permitted.

### 2.7.3.1 Steel casting

Except otherwise specified herein, all steel castings shall conform to 'standard specification for Mild to Medium strength carbon steel casting' (A.S.T.M. Designation A27-46-T, grade 63-35, of the American Society for Testing Materials). Before proceeding with foundry **work**, The Bidder shall submit to the Owner, drawings of all important steel castings, showing thereon the location of tension and end test specimens. The Bidder shall notify the Owner in time to have an Inspector present at the foundry when casting have been cleaned and are ready for surface inspection and before any repairs are made and after the castings have been annealed and before they are shipped to machine shop. No repairs shall be made to castings without the knowledge and approval of Owner. Welding shall be performed only by properly qualified welders and accordance with the best welding practice. Cracks and other defects disclosed when the casting are cleaned or during machining operations shall be chipped to sound clean metal before any repairs are made. If the removal of metal to uncover the crack or defect reduces the stresses resisting cross section of the

casting more than 50 % or to such an extent that the computed unit stress in the remaining metal is more than 50 % in excess of the following stress, the casting may, at the option of the Owner Inspector be rejected. Casting requiring welding repairs impairing the strength of the stress-resisting cross section, at any stage of the manufacture after the first annealing, shall be re-annealed, unless otherwise permitted by the Owner. All thickness and or other dimensions of the casting shall not be less than called for on the drawings by an amount sufficient, in the opinion of the Owner, to impair by more than 10 % the strength of casting of the dimensions shown on the drawings and to exceed the stresses allowed under these specifications. Casting shall not be warped or otherwise distorted, nor shall their dimensions be oversized to such an extent as to interfere with the proper fit with other parts of the apparatus. The structure of the casting shall be homogeneous and free from excessive non-metallic inclusions. An excessive segregation of impurities or alloys at critical points in a casting will be cause for its rejection.

### **2.7.3.2 Steel plates**

Steel plates for all the principal stress-carrying parts shall be fire-box quality grade B, conforming to the IS 2062 'Standard specifications for Low Tensile Strength Carbon-Steel plates of Flange and Fire box Qualities' (ASTM Designation: 185-49 T) of the American Society for Testing Materials or other recognized standards, steel plates for generating housing cover plates and other moderately stressed parts shall be fire box quality grade A or B, conforming to the above mentioned A.S.T.M. Specifications or other recognized standards. The material selected shall be suitable for the required service.

Maximum stress values shall not exceed the allowable values as given in Particular Technical Specifications or in the relevant standards and regulations and agreed by the Engineer. However, the Contractor shall be responsible for an adequate design using lower working stresses it deems this necessary or desirable.

The dimensions of the parts, which are exposed to repetitive and alternating stresses as well as to impacts and vibrations, shall take into account the safety measures and appropriate allowable stresses.

### **2.7.4 Seismic loads**

The forces being caused by earthquake including hydraulic loads, which may occur additionally, shall be taken into account for the computations.

Stresses resulting after including these loads shall not exceed permissible stresses and following provisions shall be made in the generator, Turbine and all switchyard equipment structure.

#### **2.7.4.1 Mechanical strength**

Generator, turbine, switchyard equipment and structure be designed to safely withstand earthquake acceleration force 0.3g both in the vertical and horizontal direction.

#### **2.7.4.2 Natural frequency**

Natural frequency of the machine be kept well away (higher) from the magnetic frequency of 100 Hz (twice the generator frequency). The natural frequency must be much away from multiple of runner blades passing frequency.

### **2.7.4.3 Generator stator support and bearing brackets**

Generator stator and bearing brackets of turbine and generator be designed to safely withstand horizontal and vertical forces due to earthquake.

### **2.7.4.4 Mercury contacts**

Anti vibration type mercury switch be used.

### **2.7.5 Standardisation of works**

Every effort shall be made to standardise parts, instruments and devices to minimise costs of the Works and facilitate keeping stocks, maintenance, replacement, interchange ability etc.

### **2.7.6 Surface Finish**

Surfaces to be machine-finished shall be indicated on the shop drawings by symbols. Compliance with the specified surface shall be determined by the sense of feel and by visual inspection of the work compared to applicable "Standard Roughness Specimens", or with roughness feeler gauge instruments.

Where the finish is not indicated or specified, the type of finish shall be that type which is most suitable for the surface to which it applies and shall be consistent with the class of fit required.

### **2.7.7 Fits and Tolerances**

Fits and tolerances shall be given in accordance with ISO Standard. Tolerances on matching components shall be suitable for intended service and will ensure interchange ability. Fits shall be selected for the smooth functioning of the components for fairly long life.

### **2.7.8 Materials**

In choosing materials and their finishes, due regard shall be given to the humid tropical conditions under which equipment is to work. Tropical grade material should be used wherever possible. Material specifications, including grade or class shall be shown on drawings submitted to the Owner.

## **2.8 Manufacturing Requirements**

### **2.8.1 Workmanship**

All works shall be performed and completed in highly professional manner and shall follow the best modern practices in the design and manufacturing of the equipment. All parts shall be made accurately and shall not deviate from drawing and quality requirements. Wherever, in process inspection is required, due notice shall be given to inspection agency and the inspection shall not be bypassed. The Contractor shall arrange all measuring instruments, gauges, templates, fixtures and devices required for the purpose. All special gauges, instruments and devices deemed necessary for the maintenance of the equipment, shall be offered and included in scope of supply under this contract.

## **2.8.2 Materials**

All materials used, shall be new and of first class quality free from rust, defects and imperfections. Inspection documents of all materials shall be reviewed and compiled before actual use. The Engineer shall review the inspection records of materials of major components. Materials of limited shelf life shall not be used after their expiry date.

## **2.8.3 Welding and Heat Treatment**

### **2.8.3.1 Welding**

All welding (except welding of thin plates or piping of small sizes) shall be performed by the electric-arc method and where practical, with process controlled automatic machines.

Butt welds to be welded from one side only, shall be provided with back strips on the whole length of the seam to be welded.

After being deposited, welds shall be cleaned of slag and shall show uniform sections, smoothness of weld metal, feathered edges without overlap, and no porosity and clinker. Visual inspection of the ends of welds shall indicate good fusion with the base metal.

Where weld metal is deposited in successive layers, each layer shall be thoroughly peened before the next layer is applied.

All welds transverse to the direction of flow shall be ground flush with the plates on the inside. Welds shall be ground flush on both the inside and the outside wherever dynamic stress occurs.

Particular care shall be taken in aligning and separating the edges of the members to be joined by butt-welding so that complete penetration and fusion at the bottom of the joint will be ensured. Where fillet welds are used, the members shall fit closely and shall be held together during welding.

The cut surfaces of plates requiring weld joints shall be free of all visible defects, such as laminations, surface defects caused by shearing or flame-cutting operations. The edges and surfaces to be welded shall be free of rust, mill scale, grease, oil, paint or any other foreign matter. Welding over painted surface shall be prohibited - all painting materials next to the joint to be welded shall be removed well beyond the heat-affected zone.

Where possible, welding shall be carried out in the workshop. Welding which has to be performed in the field shall be clearly indicated on drawings.

The Contractor shall maintain Weld Procedure Specifications (WPS) for the type of welds to be performed in shop. These WPS shall conform to the recommendations of material Contractors, electrode Contractors and approved standards. The WPS shall be got approved from Engineer. However, approval of the welding process shall not relieve the Contractor of his responsibility for correct welding, the use of correct electrodes and for minimising distortion in the finished structure.

Additional copies of all records of all welding procedures, including preheating and stress relieving, chemical analysis and physical properties, shall be made available to the Engineer upon request.

### **2.8.3.2 Welding Qualifications**

For welding of principal stress carrying parts, the standard of welding procedures, welders and welding operators shall conform to standards equivalent to the requirements of the ASME Boiler and Pressure Vessel Code, Sections VIII and IX or DIN 8560, DIN 8563, EN 287. For welding of less important parts, the standards and qualifications shall conform either to the AWS Standard Qualification Procedure or equivalent standards. All welders and welding operators assigned to the work shall have passed a performance qualification test. If more than one year has elapsed since the welder or welding operator passed his last test, then he shall again be tested. Welders' and welding operators' test certificates shall be submitted to the Engineer.

### **2.8.3.3 Quality and Procedure Control**

Quality control methods, e.g., radiography, ultrasonic crack detection, etc., shall be done in accordance with the appropriate manufacturing code. However, the Bidder shall indicate clearly in the Technical Data Sheets the extent to which these methods shall be used.

All welded joints, which have to be tight, shall be inspected or tested by dye penetration tests.

All major welds carried out on parts under hydraulic pressure shall be examined at least 10% radio-graphically and 100% ultrasonically. All welds on the skin-plates shall be additional dye penetration tested as directed by the Engineer.

The Contractor shall indicate in the corresponding drawings the type of non-destructive testing to be carried out during manufacture and at Site.

### **2.8.3.4 Defects and Repairs**

Plates with laminations discovered after cutting shall be rejected unless the laminated portion is only local and can easily be repaired; such repairs shall require the consent of the Engineer.

Defects in welds, which are to be repaired, shall be chipped out to sound metal and the areas to be DP or ultrasonically tested to ensure that the defective material has been completely removed before repair of welding is carried out. Repairs shall be carried out in accordance with the relevant Standards and to the approval of the Engineer. The Contractor shall be fully responsible for the in-service performance of all welding work.

The Work shall be 100% inspected again by the method used first to determine such faulty work.

### **2.8.3.5 Heat Treatment**

Heat treatment shall be performed on all fabricated parts which are stressed during service and are to be finish machined as per the approved heat treatment / weld procedure.

Heat treatment of field erection welding seams shall be performed according to the specifications for the welding procedure for the corresponding parts, which shall be submitted to the Engineer for approval.

## **2.9 Protection of Machined Surfaces**

### **2.9.1 General**

Machine-finished surfaces shall be thoroughly cleaned of foreign matter. Finished surfaces of large parts and other surfaces shall be protected with wooden pads or other suitable means. Unassembled pins or bolts shall be oiled or greased and wrapped with moisture-resistant paper or protected by other approved means.

### **2.9.2 Corrosion Protection**

All ferrous metal work shall be provided with an effective painted or galvanised finish, applied in accordance with the best trade practice to protect from corrosion.

The Contractor's services shall cover the procurement of all materials, and the preparation and application of the painting and other protective coats as specified. All costs of painting or galvanising shall be included in the Tender Price.

The Contractor shall submit for the Engineer's approval full details of the preparation, type of materials, methods and sequences he proposes to use to comply with the requirements for the protection of the Works.

#### **i) Painting**

##### **(a) Surface Preparation**

All surfaces to be painted shall be thoroughly cleaned by suitable means before application of paint. After cleaning the surfaces shall be rinsed in a manner that no residues will remain.

For removing rust and mill scale on structural steel, piping and other steel surfaces, particularly parts which will be in contact with water, exposed to heavy condensation and humidity or subjected to high temperature shall be sandblasted. Parts, which cannot be sandblasted, shall be cleaned of rust by power tool cleaning to the highest degree possible.

The sandblasted clean surfaces shall receive a shop coat with a quick-drying highly pigmented 2-pack zinc-rich primer, unless otherwise specified.

Primed surfaces contaminated with oil or grease shall be de-greased in a manner not affecting the quality of the primer. 2-component coatings older than six (6) months shall be roughened prior to the application of the next coat.

## **(b) Application Procedure**

The most commonly used methods of application are painting by brush, roller, pressure and airless spraying equipment. Selection of the application method depends on the surface to be painted. The quality of the paint shall in no way be negatively influenced.

For all paints the surface temperature of the metal shall not be higher than +50°C during the painting. Concerning special paints, the requirements set by the paint manufacturer shall be followed. All painting shall be free of cracks and blisters and all runs shall be brushed out immediately. After application of the last coat the paint system shall be free of pores.

Parts, which are embedded in concrete, shall be painted with cement base paints.

## **ii) Galvanising**

Unless otherwise specified, all fasteners and steel structures including ladders, platforms, hand rails and the like and all exterior and interior steel surfaces of outdoor Works shall be hot-dip galvanised or electrolytically galvanised.

For galvanising, only original blast furnace raw zinc shall be applied, which shall have a purity of 98.5%.

The thickness of the zinc coat shall be:

- For bolts and nuts of sizes above M36 approx. 60 micrometer and for sizes below M36, 25 micrometer.
- For all other parts, except for hydraulic steel structures or parts intermittently or permanently submerged in water, approx. 50 micrometer
- For hydraulic steel structures or parts intermittently or permanently submerged in water, approx. 100 micrometer.

Cleaning: All material to be galvanised shall be cleaned carefully of rust, loose scale, dirt, oil, grease, and other foreign matters. Particular care shall be taken to clean slag from welded areas.

Galvanising of hardware: Bolts, nuts, washers, locknuts and similar hardware shall be galvanised in accordance with the relevant standards. Straightening after galvanising: All plates and shapes which have been warped by the galvanising process, shall be straightened by being re-rolled or pressed without injury to the protective coating. Materials that have been harmfully bent or warped in the process of fabrication or galvanising shall be rejected.

## **2.10 Manufacturer's Name Plates**

Each important part to be delivered under this Contract shall be equipped with permanent nameplate in readily visible locations. The nameplates shall be protected during erection and especially during painting.

The following data shall be shown in accordance with the relevant standards:

- Manufacturer's name
- Work's serial number and year of manufacture
- Main design data.

As a general rule, standardised components, such as small or medium-sized electric motors, transformers, instruments, etc., may be delivered with the original manufacturer's standard nameplate.

Items such as valves, which are subject to handling, shall be provided with an engraved chromium plated brass name plate or label with engraving filled with enamel.

Nameplates or labels for outdoor equipment are to be of non-corrodible non-hygroscope material with lettering of a contrasting colour. Labels for indoor equipments shall be engraved with black letters on white traffolyte.

The wording of all labels shall be to the approval of the Engineer prior to the shipment of the plant or equipment.

## **2.11 Technical Works and Steel Structures**

All mechanical Works and steel structures of any mechanical or electrical installation shall comply with this General Technical Specification and the

### **2.11.1 Bolts, Screws, Nuts etc.**

All bolts, studs, screws, nuts, and washers shall be to the ISO metric system. Mild steel bolts and nuts shall be of the precision cold forged or hot forged type with machined faces parallel to one another.

All parts, other than structural steel work, bolted together, shall be spot faced on the back to ensure that nuts and bolt heads bed down satisfactorily. Mild steel nuts and bolts shall be zinc or cadmium plated. Stainless steel bolts, nuts, washers and screws shall be used for holding renewable parts in water or when exposed to high humidity

All bolts or studs which will be subject to high stress and/or temperature shall be of approved high tensile material with nuts of approved material. All bolts and studs larger than M60 shall be drilled for heaters or shall have an extension for pre-tensioning by hydraulic tools.

Fitted bolts shall be a driving fit in the reamed holes they occupy, shall have the screwed portion of a diameter such that it will not be damaged in driving and shall be marked in a conspicuous position to ensure correct assembly at Site.

The Contractor shall supply the net quantities plus 5 percent of all permanent bolts, screws and other similar items and materials required for installation at the Site. Any such rivets, bolts, screws, etc., which are surplus after the installation of the Works has been completed shall become spare parts and shall be wrapped, marked and handed over to the Owner.

## **2.11.2 Seals**

Seals shall be designed and mounted in such a manner that they are adjustable, water tight and shall be readily removed and replaced. Seals shall be moulded type and not extruded.

All adjusting screws and bolts for securing the seals and seal assembly in place shall be of stainless steel.

Seals shall be made of synthetic rubber suitable for conditions at the Site and shall be of a material that has proven successful in similar applications. Joints shall be water/oil tight.

## **2.11.3 Drives**

All moving parts of machinery including shafts, couplings, collars, projecting key heads, rope/belt-drives shall be completely guarded to provide full protection. All setscrews on revolving shafts shall be countersunk or suitably protected. All guards shall be arranged so that they can be removed without disturbing the main parts, which they protect.

All bearings shall be mounted in dust-proof housings. Base of bearing supports shall be machined, and shall rest on machined-surfaces.

## **2.11.4 Oils and Lubricants**

Efficient means of lubrication, suitable for use under Site conditions, shall be provided for all moving parts.

All different types of oils, lubricants, etc., shall be subject to the written approval of the Engineer.

Unless otherwise stated in the Particular Technical Specifications, the first oil or grease filling for bearings, pressure oil systems, transformers, etc., including the necessary quantity for flushing and for the first oil change shall be included in the Tender Price.

## **2.11.5 Piping, Fittings, Valves and Gates**

### **2.11.5.1 General**

Unless otherwise stated, all piping shall be designed for a "nominal pressure" PN 10. All piping shall be tested with 1.5 the design/nominal pressure. All required piping shall be furnished complete with flanges, joints, expansion joints, gaskets, packing, valves, drains, vents, pipe suspensions, supports, etc.

Flanged connections or joints shall be provided only as required for transport, installation or for reasons of dismantling for repair. Metric (DIN)-flanges shall be used throughout.

Adequate clearance shall be given to parallel pipes to allow for easy maintenance without disturbing other lines. All overhead piping shall have a minimum clearance of 2.00 m from operating floors and platforms.

### **2.11.5.2 Pipes & Fittings Materials**

Water, air admission and drain piping less than 25mm nominal bore shall be of galvanized heavy grade to IS-1239, Part-I or equivalent for steel pipe or copper as per relevant standards.

Water, air admission and drain piping equal to or greater than 25 mm nominal bore shall be galvanized heavy grade to IS-1239, Part I/IS-3589 or equivalent.

Oil piping greater than 25 mm nominal bore shall be of seamless high quality steel pipe conforming to minimum API-5L GR.B or equivalent grade as per process requirement, whereas pipes less than 25mm bore shall be of stainless steel.

Steel pipes of diameter 100 mm and above for a pressure of not more than PN 10 may be used in Welded type.

The minimum steel pipe wall thickness shall be the "normal" or "standard" wall thickness as stated in the applicable standards.

### **2.11.5.3 Pipe Work Fabrication**

Steel pipe work for water, air admission and drains smaller than 65 NB shall be galvanized and joined by screwed fittings. After fitting, unprotected steel be wire brushed and painted with two coats of zinc-rich paint. However, leak-free joint shall be ensured by the contractor.

Steel pipe work for water, air admission and drains 65 NB and over shall be welded ends black pipe hot-dip galvanized after fabrication.

Branches shall be made by welding or brazing. Flanged connections shall be made with approved jointing material, suitable for the duty.

All valves, pumps, etc. shall be connected to the pipe work by sufficient flanges or spherically seated unions to allow their easy removal for servicing or replacement.

No screwed or compression fittings shall be used within partitions, walls, or in inaccessible positions.

Pipes shall be cut by saw or pipe cutters and all burrs removed by reaming, Gas cutting will be permitted only if the pipe ends are ground clean and to shape for welding.

Pipes which pass through openings in walls, floors, etc. shall be clear of such openings. Any such holes or openings shall be cleanly and neatly cut or sleeved to a size sufficient to accommodate the pipe with reasonable clearance to allow for movement due to expansion.

Sleeves, in concrete shall be either non-metallic, i.e. PVC or polyethylene, or of the same material as the pipe to pass through the sleeve.

All pipes shall be supported/restrained/anchored in order to contain the forces/moments at the terminal point nozzles within permissible limits as well as not to cause any undue

localised stress and deflection/sagging anywhere along the piping length. For the above purpose standard support attachments such as clamps, saddle plates, braces, angles/cleats, guides etc. and support components such as hangers, rods, turn buckles, spring boxes etc. shall be used by the contractor.

#### **2.11.5.4 Painting**

Un-galvanized steel piping shall be painted on the exterior to prevent rusting. The paint treatment shall be of the same system as used for the turbine exterior. Paint damaged during erection and commissioning shall be repaired prior to Handing-Over.

#### **2.11.5.5 Pressure Testing**

Hydraulic piping shall be pressure tested after erection at a pressure 50% greater than nominal water pressure+ water hammering . The pressure shall be maintained without loss for one hour.

The lubricating oil piping shall be pressure tested after erection at a pressure 50% greater than operating pressure. The pressure shall be maintained without loss for one hour.

#### **2.11.5.6 Protection for transport and storage**

Oil piping shall have a protective coating applied to prevent corrosion occurring during transport and storage. The ends of the pipe lengths shall be plugged to prevent ingress of water.

#### **2.1.11.5.7 Pipe work cleaning**

Oil pipe work internal bores shall be chemically cleaned and passivated prior to use. Water, air and drain piping shall be blown through with high pressure air and flushed with water prior to use.

#### **2.11.5.8 Valves & gates**

Generally, valves shall be leak-proof in either flow direction (except for non-return valves) when the nominal pressure is applied.

All valves with design pressures higher than PN 10 and diameters larger than DN 100 shall be workshop-tested for tightness and soundness of materials.

Valves shall close clockwise and be provided with position indicators/marks on hand wheel. The drive units of motor-driven valves shall also be provided with hand wheels for manual operation.

To facilitate operation, large valves and gates shall be provided with by-pass lines for pressure balancing, if required.

Valves spindles and pins shall be of stainless steel, spindle nuts and bushes of bronze, the body of cast steel. No valve in cast iron body will be accepted.

All pressure reduction valves; safety valves and similar components shall be workshop-tested and provided with a work certificate.

### **2.11.5.9 Pipe supports and hangers**

All pipe work and accessories shall be mounted and supported in a safe and neat manner. All brackets, stays, frames, hangers and supports for carrying and staying the pipes, including their fasteners shall be included in the supply and completed by the Contractor at the Site. Pipes and fittings shall be supported at or near flanges wherever possible.

All heavy valves and other mountings shall be supported independently of the pipes to which they connect, to the satisfaction of the Engineer.

### **2.11.6 Castings**

All castings shall be free from blowholes, flaws, and cracks. All cast-iron shall be of close-grained quality approved by the Engineer.

### **2.11.7 Mechanical Instruments**

All mechanical parts of instruments shall be suitably protected against shocks and vibrations, heat, humidity and splash water, etc.

Pressure gauges shall be provided with a damping liquid, e.g., glycerine, to compensate vibrations. Pressure gauges without damping means are not permitted, unless approved by the Engineer.

### **2.11.8 Pumps**

Materials of the pumps shall be:

Casing	Cast steel
Impeller	Stainless steel
Shaft	Stainless steel
Sleeves	Stainless steel
Wear rings	Bronze
Keys	Stainless steel

The impeller diameters shall be neither maximum nor minimum impeller size for the selected pump size.

The pumps shall withstand corrosion and wear by abrasive matters within reasonable limits.

Shafts sealed by packing glands shall be fitted with sleeves. Seals shall be exchangeable without extensive disassembly of the pump. Leakage water shall be directed to suitable drainage facilities.

The size of the pump motor shall be 15 % higher than the maximum power required by the pump at any operation point

For any pump, the overall pump-motor efficiency for the specified rated head and discharge shall not be less than 60%.

### **2.11.9 Miscellaneous Metalwork**

Except where otherwise indicated elsewhere in the Particular Technical Specifications, the Contractor shall supply the following:

- All platforms, ladders, guards, handrails of tubular construction and hatch covers necessary for easy and safe access to Works
- Safety guards at each point where normal access provision would permit personnel to come within reach of any moving equipment to be provided under the Contract.

All covers for pipe, cable trenches and access hatches, required for completing the floors around and over the equipment supplied under the Contract will be supplied and installed. Unless otherwise approved, floor plates shall be of an angular pattern.

## **2.12 Electrical Works**

### **2.12.1 General**

The electrical items of Works of any electrical or mechanical installation to be provided under this Contract according to the Particular Technical Specifications shall - if not stated otherwise therein-fulfil the requirements of this Section.

All components shall be of an approved and reliable design. The highest extent of uniformity and interchangeability shall be reached. The design shall facilitate maintenance and repair of the components.

The Works shall be pre-assembled to the highest possible extent in the Contractor or Sub-Contractor's workshop, complete with all devices and wired up to common terminal blocks.

The power supply and control cables shall be laid up to these common terminal blocks. The required control and protection devices, instruments, etc., within the different scopes of work shall be supplied and connected by the relevant Contractor.

Unless otherwise agreed, ratings of main electrical Works (in feeds, bus-ties) as selected or proposed by the Contractor, whether originally specified or not, shall generally include a safety margin of 10% under consideration of the worst case to be met in service. Prior to approval of such basic characteristics, the Contractor shall submit all relevant information such as consumer lists, short circuit calculations, de-rating factors, etc.

Short-circuit calculations shall be evaluated giving full evidence that every electrical component can withstand the maximum stresses under fault conditions, for fault levels and durations obtained under the worst conditions, e.g., upon failure of the corresponding main protection device and time delayed fault clearing by the back-up protection device.

All Works shall be suitable for the prevailing climatic conditions.

The Contractor shall ensure that all the supplied Works is insensitive to any signals emitted by wireless communication equipment.

### **2.12.2 Clearances**

The layout of the Equipment on the site shall provide for ready access for operation and maintenance whilst the remaining sections of Equipment are alive. Working clearance provided between isolated Equipment and nearest live metal work shall be as per Indian Electricity rules & Standards.

### **2.12.3 Electrical Supplies for Auxiliary Equipment**

The electricity supplies available for auxiliary Equipment will be:

- (i) 415 V, 3-phase 50Hz, 4-wire for power
- (ii) 220 V, single phase, 50 Hz for lighting, indication, and anti-condensation heaters.
- (iii) 110 / 24 V D.C. for essential indication, controls, protection, alarms and circuit breaker closing and tripping supplies.
- (iv) 24 V D.C for SCADA System.

### **2.12.4 Alternating Current Supply Practice**

All mains supplies shall be switched and fuse in accordance with the requirements stated in the appropriate Section. Double-pole switches shall be used to break single-phase A.C. mains supplies.

For multi-phase supplies, each phase shall be switched simultaneously and the neutral should preferably not be switched. If it is switched, it shall be opened after and closed before the phase-lines.

All mains circuits shall be protected only in the phase-lines by fuses of suitable rating or by other suitably protective devices. The neutral shall be connected by a removable link located near the protective devices.

All mains transformers shall have an electrostatic screen which shall be earthed.

Except where the prior approval of the Engineer is obtained, wires external to the equipment shall be colored in accordance with the current IEC or relevant IS recommendation.

### **2.12.5 Direct Current Supply Practice**

It shall be possible to remove/replace cards from / to electronic equipment without damage and without interfering with the operation of the rest of the equipment or system; if necessary consideration should be given to switching off the supplies locally to a card to prevent inadvertent interference to the equipment or system during removing/replacing a card.

Power supply bus bars in cubicles shall be carefully routed and each bus bar shall be shrouded. It shall not be possible to inadvertently short bus bars either between themselves or to earth.

## 2.12.6 Electric Motors

### 2.12.6.1 General

All motors shall be of standard make, high starting torque and shall comply - as far as applicable - with IS standard motor specifications.

The general construction shall be stiff and rigid; no light metal alloy casings will be accepted. All precautions shall be taken to avoid any type of corrosion.

All motors shall be fitted with approved types of lifting hooks or eyebolts as suitable. AC motors shall have squirrel cage type rotors.

#### Motor Voltages and Power Ratings

The service voltages and corresponding power ratings for electric motors to be used in the Project shall be as follows:

- Motors above 0.75 kW
  - Service voltage : 3-phase/1-phase A.C. 415/240V, 50 Hz
  - Mode of starting : direct-on-line
- Motors up to 0.75 kW
  - Service voltage : single-phase A.C. 240 V, 50 Hz
  - Mode of starting : condenser
- Motors intended to work on the D.C. System
  - Service voltage : 24 V D.C.
  - Mode of starting : resistor

### 2.12.6.2 Rating

The rating of the motors shall be adequate to meet the requirements of its associated equipment. The service factor, being the ratio of the installed motor output to the required power at the shaft of the driven machine at its expected maximum power demand, shall be applied as follows:

<u>Power Demand of Driven Machine</u>	<u>Service Factor</u>
Up to 5 kW	1.2
More than 5 kW	1.1

A.C. motors shall be capable of operating continuously under rated output conditions at any frequency between 95% and 105% of the rated frequency and/or with any voltage variation between 90% and 110% of the nominal voltage. A transient over voltage of 130% of the nominal voltage shall as well be sustained.

Further, the motors shall be capable of maintaining stable operation when running at 70% nominal voltage for a period of 10 seconds. The pullout torque for continuously loaded motors shall be at least 160% of the rated torque and for intermittently loaded motors 200% of the rated torque.

D.C. motors shall be capable of operating continuously under rated output conditions at any voltage between 90% and 110% of the nominal voltage with a fixed brush setting for all loads. Unless otherwise approved, the speed drop between no-load and full-load shall not exceed 10% of no-load speed.

### **2.12.6.3 Starting**

A.C. motors shall be designed for direct on-line starting. They shall be capable of being switched on without damage to an infinite busbar at 110% of the nominal voltage with an inherent residual voltage of 100% even in phase opposition. For starting the motors from the individual main and auxiliary busbars, a momentary voltage drop of 20% referred to nominal voltage should be taken into consideration. With 85% of the nominal voltage applied to the motor terminals, each motor shall be capable of accelerating its associated load to full speed with a minimum accelerating torque of 5% of full load torque.

The maximum starting currents (without any tolerance) shall not exceed the following values:

- 5 times of rated current for L.V. motors rated 100 kW or above
- 2 times of rated current for D.C. motors (by means of starting resistors)

Generally, all motors shall be able to withstand five cold starts per hour, equally spaced. In addition, each M.V. motor shall be capable of enduring two successive starts with the motor initially at operating temperature. Each L.V. motor shall be capable of withstanding three successive starts under the same conditions or once every fifteen minutes without detrimental heating.

Motors for frequent automatic starting shall have an adequate rating. In the motor list the Contractor shall state the frequency of starts permitted in compliance with the motor design.

### **2.12.6.4 Insulation Class**

The insulation of all motors shall be of class F but maintain in operation the temperature limits of class B materials. It shall be suitable for operation in damp locations, for occasional contact with corrosive gases and vapours and for considerable fluctuations in temperature.

### **2.12.6.5 Ventilation and type of enclosure**

All motors shall be of the totally enclosed fan-cooled type, protection class IP 54 according to IEC Recommendation 144. Cable termination points shall be of class IP55.

Vertical motors shall be provided with a top cover to prevent the ingress of dirt, etc.

### **2.1.12.6.6 Bearings**

As far as possible, the motors shall have sealed ball or roller bearings lubricated for life. All other motors with ratings of about 1 kW and above shall be equipped with lubricators permitting greasing while the motor is running and preventing over-lubrication. Additionally, the bearings shall be fitted with grease nipples permitting the use of a universal grease gun.

Vertical motors shall have approved thrust bearings.

#### **2.12.6.7 Terminal boxes and earthing**

The terminal leads, terminals, terminal boxes and associated equipment shall be suitable for terminating the respective type of cables as specified in these General Technical Specifications and in the Particular Technical Specifications.

The terminal boxes shall be of ample size to enable connections to be made in a satisfactory manner. Supports shall be provided at terminal boxes as required for proper guidance and fixing of the incoming cable.

The terminal boxes with the cables installed shall be suitable for connection to supply systems with the short-circuit current and the fault clearance time determined by the motor protective devices.

A permanently attached connection diagram shall be mounted inside the terminal box cover. If motors are provided for only one direction of rotation, this shall be clearly indicated.

For earthing purposes, each motor shall have adequately sized bolts with washers at the lower part of the frame. In addition, each terminal box shall contain one earthing screw. Each equipment/panel shall be earthed by at least two separate earthing strips.

#### **2.12.6.8 Noise-level and vibrations**

Under all operating conditions, the noise level of motors shall not exceed 85 dB (A).

In order to prevent undue and harmful vibrations, all motors shall be statically and dynamically balanced.

#### **2.12.6.9 Tests**

Each motor shall be factory tested and shall undergo a test at site. The following tests shall be performed under full responsibility of the Contractor.

##### Workshop Tests:

- Measurement of winding resistances
- No-load and short-circuit measurements
- Measurement of starting current and torque
- Efficiency measurement (type test)
- Heat test run
- Dielectric test
- Measurement of insulating resistance

#### **2.12.7 Starters and Contactors**

Motor starters and contactors shall be equipped with short circuit protection and local disconnecting devices. Preferably, all starters shall be from one manufacturer. The control

circuit voltage shall be obtained from a 415/240 V isolating transformer with primary circuit breaker and secondary fuse. The secondary winding of this transformer shall be grounded. The operating coils of the contactor shall be connected between the grounded side of the transformer and the control contacts.

Starters and contactors shall comply with IEC 292.1 or NEMA IC 1 and be suitable for direct on-line starting, uninterrupted electrical duty, and capable of 30 operations per hour. They shall be installed in ventilated enclosures for indoor installation and weatherproof enclosures for outdoor installation, unless otherwise approved by the Engineer. The enclosures shall be complete with locks, cable sealing boxes, conduit entries, cable gland plates, bus bars, internal wiring, terminal boards, etc. as required by the duty of the starter or contactor.

Starters and contactors shall be of minimum size compatible with motor size and capable of satisfactory operation, without damage, for a period of 5 minutes at a voltage 25 percent below nominal, at nominal frequency.

Thermal type overload and phase failure relays shall be supplied with starters for motors of 7.5 kW or greater. For motors of less than 7.5 kW, suitable rated 3-phase thermal overloads will be acceptable. Ammeters to read current in one phase shall be provided for motors above 7.5 kW.

Each starter shall have sufficient number of auxiliary contacts required for interlocking and indication purposes plus two spare convertible contacts for Owner's use.

### **2.12.8 Moulded Case Circuit Breakers**

All moulded case circuit breakers shall be of 2 or 3-pole type as required, having thermal time delay and instantaneous trips with "On-Trip-Off", indicating/operating mechanism. Circuit breakers used in combination type motor starters or contactors shall have the operating mechanisms interlocked with the starter or contactor cover so that the cover cannot be opened unless the circuit breaker is open. The breakers shall comply with applicable section of IEC60157/1 or equivalent standards.

### **2.12.9 Control Relays**

Relays used as auxiliary control devices in conjunction with motor starters and magnetic contactors shall be of the type designed for machine tool application featuring contact convertibility. All contacts shall have a minimum thermal current rating of 10A over a range of 6 to 600 V AC.

### **2.12.10 Terminal Blocks**

All terminal blocks shall be mounted in an accessible position with the spacing between adjacent blocks not less than 100 mm and space between the bottom blocks and the cable gland plate being a minimum of 200 mm. Sufficient terminals shall be provided to allow for the connection of all incoming and outgoing cables, including spare conductors and drain wires.

In addition, 20 percent spare terminals shall be provided. In enclosed cubicles, the terminal blocks shall be inclined toward the door for facilitating terminations.

Terminals shall be of the channel mounting type and shall comprise a system of individual terminals so that terminal blocks can be formed for easy and convenient cabling consistent with the high reliability required of the circuits.

Terminal blocks shall be provided with shorting links and paralleling links where applicable and mounting identification numbers and/or letters.

Terminal blocks shall conform to the applicable standards. The smallest size to be used shall be designated for 2.5-sq. mm wire and not more than two conductors shall be connected under one terminal clamp.

Terminal identification shall be provided corresponding to wire number of connected leads.

Circuit terminals for 415 V AC shall be segregated from other terminals and shall be equipped with non inflammable, transparent covers to prevent contact with live parts. Warning labels with red lettering shall be mounted thereon in a conspicuous position.

#### **2.12.11 Equipment Wiring**

All wiring connections shall be readily accessible and removable for test or other purposes. Wiring between terminals of the various devices shall be point to point.

Multi-conductor cables shall be connected to the terminal blocks in such a manner as to minimise crossovers. Approved claw washers of crimp type connector shall be used to terminate all small wiring. Each conductor shall be individually identified at both ends through a system providing ready and permanent identification, utilising slip-on ferrules approved by the Engineer.

Markers may be typed individually or made up from sets of numbers and letters firmly held in place. Open markers will not be accepted.

Markers must withstand a tropical environment and high humidity and only fungus proof materials will be accepted. Ferrules of adhesive type are not acceptable.

All trip circuits shall employ markers having a red background.

#### **2.12.12 Cubicles and Control Panels**

Cubicles and control panel enclosures shall be of sheet steel with minimum thickness of 2.5 mm, of rigid, self-supporting construction and supplied with channel bases.

Cubicles shall be fitted with close fitting, gasketed, hinged, lift-off doors capable of being opened through 135 deg and above. The doors shall be provided with integral lock and master key.

Cubicles and panels shall be vermin proof. Removable gland plates shall be supplied and located to provide adequate working clearance for the termination of cables. The cables and wiring shall enter from bottom or top as approved or directed by the Engineer.

The cubicles and panels shall be adequately ventilated, if required, by vents or louvers. All ventilating openings shall be provided with corrosion-resistant metal screens or a suitable filter to prevent entrance of insects or vermin. Space heating elements with thermostatic control shall be included in each panel.

Where cubicles are split between panels for shipping, terminal blocks shall be provided on each side of the split with all necessary cable extensions across the splits. These cable extensions shall be confined within the panels with suitable internal cable ducts.

Unless stated otherwise, all cubicles and panels shall be provided with a ground bus with 40mm copper bar extending through out the length. Each end of this bus shall be drilled and provided with lugs for connecting ground cables ranging from 70 to 120mm<sup>2</sup>.

All instruments, control knobs and indicating lamps shall be flush mounted on the panels. Relays and other devices sensitive to vibration shall not be installed on doors or hinged panels, and no equipment shall be installed on rear access doors.

The instrument and control wiring, including all electrical interlocks and all interconnecting wiring between sections, shall be completely installed and connected to terminal blocks by the manufacturer.

The arrangement of control and protection devices on the panels and the exterior finish of the panels shall be subject to the approval of the Engineer. The interior of all cubicles and panels shall have a mat white finish unless specified otherwise.

Switched interior light and socket outlets shall be provided for all cubicles and control panels.

All cubicles and control panels shall be provided with nameplates, identifying the purpose of the panel and all of its components.

### **2.12.13 Earthing**

Provision shall be made for earthing all equipment intended for connection in an A.C. mains supply. All structural metal work and metal chassis shall be connected to earth. Connection between circuits and metal work shall only be made for reasons of safety and/or reduction of interference. Where such connections are made, they shall not be used as normal current-carrying earth returns.

Earthing conductors shall be at least equal in cross-sectional area to the supply conductors and shall be capable of carrying the fault current.

### **2.12.14 Labels and Plates**

Labels and data plates shall be provided in accordance with applicable standards and as detailed hereunder.

The proposed material of the labels, size, exact label lettering and proposals for the arrangement of the labels shall be submitted to the Engineer for approval.

Labels written in the Contract language shall be provided for all instruments, relays, control switches, push buttons, indication lights, breakers, etc. In case of instruments, instrument switches and control switches, where the function is indicated on the device, no label is required. The label shall be fixed close to the devices in such a way that easy identification is possible.

Each separate construction unit (cubicle, panel, desk, box, etc.) shall be identified. Cubicles and similar units shall also bear this identification number on the rear side if rear access is possible. The overall designation of each unit shall be given in the Contract language and - if required - also in a selected local language. These labels shall be made of anodised aluminium with black engraved inscriptions, arranged at the top section of the units. Manufacturer's trade labels shall - if desired - appear in the bottom section of the units.

All Works inside cubicles, panels, boxes, etc., shall be properly labelled with their item number. This number shall be the same as indicated in the pertaining documents (wiring diagrams, Works list, etc.).

Instruction plates in the Contract and selected local language, the sequence diagrams or instructions for maintenance shall be fitted on the inside of the front door of the electrical switchboards.

#### **2.12.15 Warning Labels**

Warning labels shall be made of synthetic resin with letters engraved in the Contract and selected local language, where required in particular cases.

For indoor circuit breakers, starters, etc., transparent plastic material with suitably contrasting colours and engraved lettering would be acceptable.

#### **2.12.16 Labels for Cables**

Each cable when completely installed shall have permanently attached to each end and at intermediate positions as may be considered necessary by the Engineer, non-corrosive labels detailing identification number of the cable, voltage, and conductor size.

The cable identification numbers shall comply with those of the cable list.

All cables in cable pits and at the entry to buildings shall be labelled utilising the aforementioned type of label.

#### **2.12.17 Single-Line Diagrams**

Each switchgear room shall be furnished with a copy of the final as-built single-line diagram detailing all electrical data and denominations, separate for each individual switchgear / distribution board / MCC, placed under glass and frame/wall mounted at an approved location.

The same applies to the Station Single-Line Diagram one copy of which shall be arranged in the control room(s).

### **2.12.18 Key System for Electric Boards**

Key interlocked switches shall be provided with approved locks for locking in the neutral position. Similar locks shall be provided for selector switches for locking the switches in any of the positions.

The locks or padlocks shall be co-ordinated for the different applications and shall be supplied with three keys. The cabinet door keys shall be similar and shall be six (6) in number.

### **2.13 Instrumentation and Control Equipment**

#### **(a) Design Criteria**

All components shall be of an approved and reliable design. The highest extent of uniformity and interchangeability shall be reached. The design shall facilitate maintenance and repair of the components.

The Works shall be pre-assembled to the highest extent in the Contractor's or Sub-Contractor's workshop, e.g., shop welding of thermometer wells and other connections, wiring of boards, desks, etc., including internal wiring and installation of devices shall be carried out. Fragile instruments shall be removed for transportation to site.

All components shall be suitable for continuous operation under site conditions.

Materials for instrumentation and control equipment, including piping material, which is exposed to the measured media, shall be selected accordingly.

All components shall be compatible with other electrical, electronic and mechanical Works.

All instrumentation and control functions shall be shown on the piping and instrumentation diagrams. The symbols to be used shall be in accordance with ISO standard. The identification system (tag numbers) shall be in accordance with the Works identification system and is subject to approval by the Engineer. All measurements and alarms shall be listed in a measuring list of a standard form subject to Approval by the Engineer. For remote controls, a schedule of interlocks shall be provided. The features of automatic controls shall be shown in block diagrams.

Shielded cables shall be provided for the control and supervisory equipment where required.

#### **(b) Sizes of Indicators, Recorders Etc.**

The meters, instruments and recorders shall be of standard size, to be selected to guarantee unique appearance of switchgears, control panels, control desks, etc. The front glasses shall be of the anti-glare type. The scales shall be 90 degrees type for local control

panels but must be 240 degrees type for control room instrumentation where ever analogue meters are selected.

### **(c) Measuring Systems**

Electric measuring signals of 4-20 mA shall be transmitted to the control room for essential or regulating circuits. In this case the absence of live zero signal shall lead to a warning signal. Measuring signals for indicating purposes will be 4-20 mA.

The components shall quickly respond to any changes of the measured magnitudes. Measuring ranges of indicators, transducers, etc. shall be selected in such a way that the rated value of the measured magnitude covers approx. 75% of the range.

All local instruments shall, as far as practicable, be mounted vibration free to allow good reading. Wherever required, damping elements shall be used. Corresponding systems shall be grouped together in local panels. The binary sensors shall be used separately and supplied with 24 V D.C.

#### **2.13.1 Temperature Measurement**

Resistance thermometers shall be equipped with water proof connection leads. The temperature sensors shall be selected in such a way to minimise the number of different spare inserts.

Resistance thermometers shall be used as far as possible and shall generally be of type Pt 100.

#### **2.13.2 Pressure Measurements**

Pressure gauges shall be shock and vibration-proof (preferably by filling with glycerine) and shall be equipped with toothed wheels and toothed segments of the machined type. They shall completely be made of stainless steel.

The error for pressure transmitters shall be limited to  $\pm 0.5\%$ .

Each gauge, pressure switch and transmitter for absolute or differential pressure shall be equipped with a pressure gauge isolating valve including a test connection of the screwed type M20 x 1.5 mm so that such device can be removed without any disturbance of the plant operation.

If the pressure is pulsating, the devices concerned shall be connected via flexible tubes or other pulse-absorbing means.

The adjustment of the pointer shall be possible by means of an adjustment device without removing the pointer from its axle.

All casings shall be dust and watertight and be made of stainless steel.

#### **2.13.3 Level Measurements**

The liquid level measurements in reservoirs and tanks with atmospheric pressure shall be made by means of pressure sensor/ultra sonic / laser type. The errors shall not

exceed  $\pm 1.0\%$  of the total measuring range. Level switches shall be of the externally mounted type.

#### **2.13.4 Electrical Measurements**

All Electrical instruments shall be of flush mounted design, dust and moisture-proof. A.C. ammeters and voltmeters shall have digital type system of not less than 1.5 accuracy class for connection to the secondary side of instrument transformers. D.C. measuring instruments shall have digital type systems of the same accuracy. Wattmeters/energy meters shall have electro-dynamic measuring mechanisms if fed by transmitters. Wattmeters shall be suitable for unbalanced systems and accuracy of energy meters should be of 0.2 % accuracy class.

All indicating instruments shall generally withstand without damage a continuous overload of 20% referred to the rated output value of the corresponding instrument transformers. Ammeters shall not be damaged by fault-currents within the rating and fault duration time of the associated switchgear via the primaries of their corresponding instrument transformers.

All instruments and apparatus shall be capable of carrying their full load currents without undue heating. All instruments and apparatus shall be rear connected, and the enclosures shall be earthed. Means shall be provided for zero adjustment of instruments without dismantling.

When more than one measured value is indicated on the same instrument, a measuring point selector switch shall be provided next to the instrument and shall be engraved with a legend specifying each selected measuring point.

Scales shall be arranged in such a way that the normal working indication is between 50-75% of full scale reading permitting an accurate reading. CT connected Ammeters provided for indication of motor currents shall be provided with suppressed overload scales of 2 times full scale. The dials of such ammeters shall include a red mark to indicate the full load current of the motor.

All instruments mounted on the same panel shall be of same style and appearance.

All metering circuits shall be terminated in marked terminal blocks for remote metering purposes.

#### **2.13.5 Position Measurements**

Position transmitters for continuous position indication and measuring transducers shall have an output current of 4-20 mA and aux. supply voltage (if required) 24V D.C.

#### **2.13.6 Proximity Switches**

Proximity switches shall be mounted suitable for easy adjustment and for rigidly locking in position after being adjusted. They shall be of heavy-duty rating and have two changeover contacts suitable for 24 V D.C. operation.

Switch fixings shall be positive and shall be unaffected by vibration. At the same time they should be capable of easy adjustment to suit changing parameters of the associated plant.

Particular attention shall be paid to potentially harmful environmental conditions, including water, oil, dust, dirt, temperature variations and differential expansions..

### **2.13.7 Contact Devices**

Contacts of level switches, pressure switches, temperature switches, proximity switches, and of all other devices shall be of the snap action type . Contact devices for interlocking systems shall be separate, i.e., contact devices serving commonly for interlocking and other purposes will not be accepted.

### **2.13.8 Protection Systems**

Electrical/Mechanical Protection and Interlocking Systems shall be provided for all works components and individual systems to ensure a safe and reliable operation and to limit harm and damage to personnel and works to an utmost extent.

The primary functions of these facilities shall be to disconnect selectively faulty sections of the systems prior to influence or damage to other works and to maintain operative systems as far as possible.

Moreover these devices shall facilitate the duty of the operation staff and prevent mal-operation.

## **2.14 Inspections and Tests**

### **2.14.1 General**

Approval of assemblies, tests, inspections, related procedures etc. and acceptance of pertinent test and inspection certificates, or waiving of inspections or tests, shall in no way relieve the Contractor of his contractual obligations for finishing the Works in accordance with the provisions of the Specifications.

Three (3) sets of all test records, test certificates, performance curves, tables etc. of all inspections and tests, whether or not attended by the Engineer shall be supplied after each inspection or test. After completion of all testing two (2) sets of the above mentioned documents shall be supplied properly bound in books.

All test certificates shall be endorsed with sufficient information for identification of the equipment and material to which the certificates refer.

### **2.14.2 Workshop Inspections and Tests**

As far as practicable, quality of materials, workmanship and performance of all items of the Works to be furnished under this Contract shall be inspected at the places of manufacture.

Where the Contractor desires to use stock material, not manufactured specifically for the Works, satisfactory evidence that such material conforms to the requirements of the Contract shall be submitted.

Free and unrestricted access to the Contractor's factory and shops (including those of his Subcontractors) shall be granted to the Engineer also and upon reasonable notice by the Engineer if deemed necessary by the same for additional witnessing of assembly work or inspections and tests.

### **2.14.3 Material Tests**

Unless otherwise specified, the quality of materials shall be verified generally by:

- Chemical analysis
- Mechanical tests (yield point, tensile strength, elongation, and notch impact.)
- Welding tests (welding procedure, welding material, welding tensile strength, welding bend test, welding reversed bend test, etc.)
- Non-destructive x-rays, ultrasonic, magnetic particle, liquid tests, penetration inspection, etc.).
- Electrical tests (voltage, losses, tan delta, insulation, magnetic properties etc.)

Certified mill test reports of plates will be acceptable when these comply with the requirement of specifications. Test specimen and samples for analysis shall be plainly marked to indicate the materials they represent.

Castings and forgings shall be tested in the rough state in order to detect flaws in good time thus avoiding delays. Magnetic particle inspection of important castings shall cover the whole surface of the casting. After partial machining further tests can be conducted.

Load tests on crane hooks, steel wire ropes, chains and other lifting devices, etc. shall be considered as material tests.

### **2.14.4 Checking of Dimensions**

The dimensions, especially clearances and fits, (ISO 286) which are essential for operation and efficiency shall be carefully checked in an approved manner, as for example:

- run out and roundness tolerances of shafts, pistons, etc., to be measured on single parts,
- fits and clearances of bearings, servomotor pistons, valves, guiding, distributing and actual actuating elements, etc.,
- Accuracy, surface roughness and shape of sliding and guiding surfaces of seals, bearings, water passages in hydraulic machinery, valves, etc.,
- Dimensions of couplings or connections for assembly with other deliveries from the Contractor, Sub-contractors or other contractors.

### **2.14.5 Workshop Assembly**

In addition to the quality and production control tests, the following shop assembly work and tests shall be made to check measurements, fitting and functioning.

Works to be furnished shall be shop assembled to a status sufficient to prove that the design and workmanship have been executed in accordance with the Specifications, that the delivery is complete, and that no work remains to be done at Site, which reasonably can or should be done in the shop.

Where applicable, each item of the Works shall be assembled completely prior to painting.

Field joints shall be temporarily connected. All parts shall be properly matched marked, identified and doweled where practicable, to facilitate correct and quick field assembly and alignment. Where necessary, suitable dowels shall be provided for insertion after field assembly and drilling. The holes for any fitted bolt shall be accurately reamed.

During workshop assembly all instruments, control devices and piping shall be fitted. If the assembly shows defects in the design or manufacture or unforeseen difficulties in assembling and dismantling, these shall be eliminated. If required, design alterations or corrective measures can be executed provided that reliability of operation or interchangeability are not reduced and provided that the agreement of the Engineer has been obtained.

If the corrections cannot be carried out in accordance with the terms mentioned above, the components concerned will be rejected. The decision on possible subsequent corrections is reserved exclusively to the Engineer. Faulty parts or Works shall by no means be delivered. The assembled parts shall subsequently be subject to tests as per applicable standards or required by the Engineer.

### **2.14.6 Pressure and Leakage Tests**

All parts subject to internal or external pressure or containing any liquids or gases temporarily or permanently during operation shall be tested prior to painting.

In addition to the Specifications, the applicable and approved standards and official regulations shall be observed. If any liquid is used for the test that may cause corrosion, all Works and piping shall be thoroughly cleaned immediately after the test.

Leaks and defects can be repaired if permitted by the applicable standards and approved by the Engineer. If defects are found, the Engineer may reject the defective parts, or permit welding repairs with stress relieving, radiographic examination and additional pressure tests.

### **2.14.7 Parts Exposed to Hydraulic Pressure**

Unless otherwise specified or required, the following shall apply: the hydraulic pressure tests shall be carried out using the liquid to be used during operation or a liquid with less viscosity.

The hydraulic test pressure shall be 1.5 times the maximum operating pressure and shall be maintained for a period of 30 minutes. Afterwards the test pressure shall be reduced to the operating pressure.

#### **2.14.8 Functional Tests**

Functional tests shall be defined as tests of the function of assemblies, sub-assemblies or parts of the Works under no load conditions. Functional tests shall be performed on all Works prior to the execution of operational tests.

#### **2.14.9 Operational Tests**

As far as practicable operational test shall be carried out on all Works, simulating operating conditions.

Parts to be delivered by sub-Contractors shall be tested either at the premises of the sub-Contractor or of the Contractor, as agreed by the Engineer.

Testing of the electrical Works shall be performed in accordance with applicable Standards; they shall include but not be limited to tests of heating, loading, overloading, and losses.

Operational tests of lifting equipment and other machinery shall include tests under nominal load and 125 % of nominal load unless otherwise specified.

#### **2.14.10 Electric Tests**

Electrical Works shall be tested in accordance with applicable Standards and agreed test programs and procedures.

#### **2.14.11 Type Tests**

Type tests certificates shall be enclosed with the bid, however type tests for certain parts of the work or works shall be carried out as specified or agreed between Contractor and Engineer.

### **2.15 Erection and Commissioning**

#### **2.15.1 Preparation and Installation**

Prior to commencement of installation, the Contractor shall closely inspect the site and all the foundations and other structures on which parts of the plant supplied under this Contract will be installed; he shall check that the foundations conform to the installation drawings.

#### **2.15.2 Reference Points**

The Contractor shall employ a competent surveyor for setting-out of all datum lines including the constant checking and maintenance of the setting-out until the completion of his works.

The Contractor shall provide all necessary pegs and centre lines and shall establish all such permanent markings and recovery marks as may be required by the Engineer for checking the Contractor's setting-out. The Contractor shall be responsible for rectifying, at his own cost, all work rejected by the Engineer due to errors in setting-out.

The Contractor shall be responsible for the true and proper staking-out of the works and levels of reference given by the Engineer in writing, for the correctness of the positions, levels, dimensions and alignment of all parts of the works and for the provision of all necessary instruments, appliances and labour in connection with this.

The checking of any staking-out or of any line or level by the Engineer or the Engineer's Representative shall not in any way relieve the Contractor of his responsibility for its correctness.

### **2.15.3 General Notes on Installation Work**

All transportation and handling of the plant from the place of storage to the place of installation shall be carried out by the Contractor. He shall provide all hoisting equipment, staging and scaffolding, winches and wire ropes, slings, tackles and all other appliances and temporary materials.

The Contractor shall comply with all applicable and approved safety regulations while carrying out the works on Site and with all reasonable requirements of the Engineer. This stipulation shall in no way release the Contractor from any obligation concerning his liability for accidents and damages. He shall be responsible for adequate protection of persons, plant and materials against injuries and damages resulting from his operations.

The alignment of the plant shall be done exactly; the tolerances indicated by the Manufacturers or in the drawings shall be kept.

Setting of parts to be aligned shall be performed by means of fine measuring instruments. All erection clearances and settings shall be recorded. Copies of these records shall be given to the Engineer. After alignment, the parts shall be held firmly in position by means of set pins, fitted bolts, etc.

All parts to be embedded in concrete shall be set accurately in position and shall be supported rigidly to prevent displacement during the placing of concrete. Adjusting screws and bolts shall be drawn tight and secured adequately. Steel wedges shall be secured by welding. Wooden wedges shall not be used.

The Contractor shall verify carefully the position of all parts to be embedded before concrete is poured. All important measurements and dimensions shall be recorded. Copies of these records shall be given to the Engineer for checking and approval before items are built-in to the Works.

After concreting, the control measurements shall be verified again, indicated in the above-mentioned records and submitted to the Engineer.

The Contractor shall provide all necessary anchors and braces to ensure the alignment and stability of the parts to be installed. All temporary anchors and bracings shall take care of all dead load, wind load, seismic and erection stresses, e.g., during concreting, and shall remain in place until they can be removed without endangering the stability of the plant.

If for installation purposes auxiliary structures have been attached to the plant, they shall be removed after completion of work and the surface restored to proper condition by grinding and repainting.

Special care shall be taken not to damage surfaces of galvanised or specially treated plant during erection. Care shall be taken to prevent or remove any rust streaks or foreign matters deposited on galvanised or otherwise finished surfaces during storage or transport or after installation.

Glass parts or other parts, which can easily be damaged, shall be provided with suitable protective sheaths or coverings during installation.

Machined or bare metal surfaces, which are to receive no coat of paint, shall be protected during transportation, storage and erection by a suitable anti-corrosion film.

All power tools preferably are operated pneumatically. They are to be handed over at the end of the installation work in good condition in accordance with the Engineer's instructions.

After erection, the works shall be finally painted, in accordance with the painting specification, and any damaged paintwork shall be restored.

The Contractor shall keep the site in clean condition during erection and commissioning time. On instruction of the Engineer he shall remove waste from the place of installation to the defined deposit site at his own cost.

## **2.16 Painting of Works at Site**

### **(a) Painting Materials**

Coating materials shall be standard products of a paint manufacturer with proven experience in the field of corrosion protection of the type of Works to be supplied.

Paint material shall be delivered in unopened original containers bearing the manufacturer's brand name and colour designation, storage directions and handling instructions. The entire paint material for a particular specified paint system shall be supplied by one manufacturer only; who shall guarantee the compatibility and quality of the paint material. A complete list of the proposed paint material shall be submitted to the Engineer. For multicoated painting systems each coat shall have a different colour.

With regard to materials, the Contractor shall submit full details including the source of the basic raw materials, volatile matter content, nature of solvent, number of components, type of coat, coverage, time interval between coats and number of coats,

compatibility of each coat with the previous coat, toxic properties, physical properties, shelf life, resistance against chemical attack, resistance against ozone and UV-radiation, compatibility with drinking water standards, etc.

He shall describe in detail the treatment he proposes to apply in order to give adequate protection during transport, site storage, building and concreting and subsequent erection.

The Contractor shall submit to the Engineer for approval an overall colour scheme in accordance with the Particular All final coats shall be in the colours approved by the Engineer. On request of the Engineer, painting samples for the different coats and colours shall be provided.

All pigment, paints and primers shall be delivered to Site in sealed containers packed by the manufacturer. The manufacturer's instructions for preparation and application of all painting and protective coats shall be strictly observed.

**(b) Preparation of Paint Material**

Paint shall be delivered ready mixed wherever possible. Adding of diluting agents and mixing of two or multi-component systems shall be done in the field in accordance with the directions of the manufacturer. After mixing, the paint shall be poured into a clean container to ensure that no settled pigments are at the bottom.

**(c) Application**

The most commonly used methods of application are painting by brush, roller, pressure and airless spraying equipment. Selection of the application method depends on the surface to be painted. The quality of the paint shall in no way be negatively influenced. The manufacturer's directions shall govern the choice of application method. Inaccessible surfaces shall be painted prior to erection with prime and finish coats according the specification. Areas inaccessible to spraying equipment shall be painted by brush. Corners and edges shall be pre-coated. Bolts, screws, studs, rivets etc. shall be painted as a whole with the complete paint system after erection.

The primer shall be applied to an absolutely clean and dry surface only. Temperature and dry-out time shall be in accordance with the manufacturer's directions. Whenever possible the prime coat as well as one intermediate coat shall be applied in-doors at the Contractor's shop.

During painting the air temperature shall be at least +5°C and the temperature of the items being painted must be at least 3°C above the dew point. During drying of the paint, the temperature shall not be below 0°C. For all paints the surface temperature of the metal shall not be higher than +50°C during the painting. Concerning special paints, the requirements set by the paint manufacturer shall be followed.

Cleaning and painting work shall be interrupted outdoors and in non-conditioned rooms under the following conditions: rain, fog, dew, and polluting winds, sand and other dusts. Surface preparation and application of the first paint layer are parallel operations to be carried out within a maximum delay of 4 hours.

All painting shall be free of cracks and blisters and all runs shall be brushed out immediately. After application of the last coat the paint system shall be free of pores. After erection of the equipment all damages to painted surfaces shall be repaired. Welds, rusty spots, slags, beads, flux deposits etc. shall be repaired and repainted. For touching up, the same materials shall be used as for the main painting work. Repaired finish coats shall be of the same appearance as the original coating.

Remove electrical plates, surface hardware, fittings and fastenings before starting painting operations. Carefully store, clean, and reinstall after completion of work.

**(d) Repair of Primer and Finish Coats**

For touching up, the same paint shall be used as for the original painting work. Repaired finish coats shall be of identical appearance with the original and no difference in the colour shall occur.

**(e) Galvanised and Painted Structures**

Surface Preparation: Thorough cleaning of the damaged surface i.e. removal of oil, grease, dust, etc.

Repair of Coatings: Two coats of 2-component epoxy-resin micaceous iron oxide (mio) paint. Total film thickness min. 0.160 mm. The colour of the paint shall be the same as originally applied.

**(f) Painted Structures**

Repairs on painted structures shall be carried out as follows:

Surface Preparation: Scraping, wire brushing or grinding to Grade ST 3 according to IS 055 900-1967.

Prime Coat: One coat of 2-component epoxy resin zinc-chromate primer. Dry film thickness minimum 0.050 mm.

Parts, which are embedded in concrete, must not be protected against corrosion. However, transition zones of large steel pipes and of steel linings shall be painted over a length of 1 m within the concrete, all other concreted in steel surfaces over a length of 200 mm within the concrete.

**(g) Quality Control of Painting**

The minimum dry-film thickness prescribed in these Specifications shall be observed. Of each 100 m<sup>2</sup>, one area of 10 m<sup>2</sup> will be measured for dry-film thickness. No measured thickness shall be less than the specified thickness. Where the minimum thickness is not achieved, the coat shall be repaired to reach the specified minimum dry-film thickness.

The dry-film thickness shall be measured by approved gauges to be arranged by Contractor.

Upon completion of each coat, the painter shall make a detailed inspection of the painting finish and shall remove from adjoining work all spattering of paint material. He shall make good all damage that can be caused by such cleaning operations.

A detailed inspection of all painting work shall likewise be made, and all abraded, stained, or otherwise disfigured portions shall be touched up satisfactorily or refinished as required to produce a first-class job throughout and to leave the entire work in a clean and acceptable condition.

## **2.17 Site Inspection and Tests**

During erection, commissioning and trial operation, the Contractor shall perform at suitable intervals all inspections and tests in the presence of the Engineer in order to prove the orderly execution of the works in accordance with the Contract.

Unless otherwise specified, all costs for testing at site and of the works and charges associated with it shall be borne by the Contractor. This includes the measuring devices, properly calibrated, and any pertinent accessories, which shall be made available by the Contractor for the entire duration of the tests. The Contractor shall delegate his experts to perform the tests at site.

The Engineer reserves the right to have checked at his own expenses the Contractor's instruments to be used or having been used for any tests by an independent, officially acknowledged institution.

The Contractor's testing at Site shall be complete in every respect to prove the successful performance and operation of all the works and Works supplied and erected under the Contract.

In case of disagreement between the Engineer and Contractor(s) on the test results, an independent expert shall be appointed by Owner to whom both parties shall agree. If no amicable settlement can be reached, the Arbitration Clause shall be applied.

For the procedure of inspections and test at site, notice to the Engineer, reports, commissioning, trial runs and trial operation, and acceptance tests refer to General Conditions of Contract.

## **2.18 Commissioning Test**

After carrying out all field tests as stipulated in Technical Specification commissioning tests shall be carried out on all generating units to verify the rating characteristics of generating units and other equipment's in accordance to relevant standards.

The test run on generating units shall be carried out as per relevant provisions of IEC standards.

## **2.19 Trial Run & Commercial Operation**

- i) Immediately upon completion of commissioning, the plant shall be kept on trial operation during which period all necessary adjustments shall be made while operating over the full load-range enabling the plant to be made ready

for performance and guarantee tests. The duration of trial operation of the complete equipment shall be 72 hours continuous run.

The trial operation shall be considered successful, provided that each item of the equipment can operate continuously at the specified operating characteristics, for the period of trial operation.

For the period of trial operation, the time of operation with any load shall be counted. Minor interruptions not exceeding 4 (four) hour, at a time, caused during the continuous operation shall not affect the total duration of trial operation. However, if in the opinion of the Purchaser, the interruption is long, the trial operation shall be prolonged for the period of interruption.

The trial operation report comprising of observations and recordings of various parameters to be measured in respect of the above trial operation shall be prepared by the Contractor. This report, besides recording the details of the various observations during trial run, shall also include the dates of start and finish of the trial operations and shall be signed by the representatives of both the parties. The report shall have sheet, recording all the details of interruptions occurred, adjustments made and any minor repairs done during the trial operation. Based on the observations, necessary modifications, repairs to the plant shall be carried out by the Contractor to the full satisfaction of the Purchaser to enable the latter to accord permission to carry out the performance and guarantee tests on the plant. However, minor defects, which do not endanger the safe operation of the equipment, shall not be considered as reasons for withholding the aforesaid permission.

During the trial run the Contractor shall make familiar the Purchaser's personnel with the equipment, the operation and maintenance of the Works and its auxiliaries to such extent that thereafter the duties can be assigned to the Purchaser's trained personnel.

If any defects or irregularities affecting the safety or reliability of the Works should arise during the trial run, the trial run shall be interrupted and started again after such defects or irregularities have been corrected by the Contractor.

- ii) After successful trial run, generating units shall be put for commercial operation under the supervision of Contractor for three months. During the three months of operation, Contractor shall be fully responsible for technical guidance to operating staff of the Owner.

## **2.20 Acceptance**

The taking-over testing of any part or section of the Permanent Works, which can operate as an independent unit, shall be performed as per the test procedure agreed upon between Engineer and Contractor.

Immediately upon termination of any such testing of a part or section of the permanent Works a "Protocol of Acceptance" which shall be deemed to be the Test Certificate required by General Conditions of Contract shall be issued by the Engineer.

This document shall be signed by an authorised representative of the Purchaser, the Engineer and the Contractor and shall form an integral part of the later "Taking-Over Certificate".

This "Protocol of Acceptance" shall state:

- The date of testing
- The quantity and type of Works concerned
- Statement of all minor defects which have to be corrected by the Contractor
- Confirmation that the guaranteed data have been proven

If any test for the verification of the guaranteed data could not be performed for operational reasons beyond the Contractor's responsibility, this part of the acceptance shall be stated in the "Protocol of Acceptance" and be postponed for a mutually agreed period.

However, the tested part or section of permanent work shall continue to be operated by the Purchaser with the help of Contractor's personnel, till all Generating units have been tested and commissioned and trial run period of 10 days or that to be agreed with the Owner and the Contractor, has been completed in respect of last unit to be commissioned.

Before issuing the "Taking-Over Certificate", the revised copies of the Operation and Maintenance Manual shall be submitted together with the specified number of complete sets of drawings of the Works as completed and final GTPs. The Works shall not be considered complete for purposes of taking over under the terms of the General Conditions of the Contract until the above documents have been supplied by the Contractor.

## **2.21 List of Applicable Standards**

As per list given in references at 1.2 above.

## **3.0 TECHNICAL SPECIFICATIONS FOR FRANCIS TURBINE**

### **3.1 Scope**

The scope of work under this section should include design, material selection, manufacture, shop assembly and testing, transportation and delivery to site, insurance, storage at site, installation, commissioning, field acceptance tests, warranty and other services as specified or required.

### **3.2 Detailed list of major items should be as follows**

#### **3.2.1 Turbine**

- a. Type of turbine - Francis (complete with all embedded, removable static, rotating parts)
- b. No of units - As per specific power project
- c. Shaft - Horizontal or vertical
- d. Rated power at rated Head and rated discharge -
  - Turbine model testing
  - Tools, slings and handling devices for assembly and maintenance of turbine
  - Transportation and delivery at site
  - Site installation, commissioning and acceptance tests
  - Insurance for transit, storage at site, erection testing and commissioning

- Preparation and submission of operation and maintenance manual and training of O&M staff in optimum use of these manuals
- Set of spare parts for five years of trouble free operation. A schedule of spare parts should be annexed.

### **3.2.2 Auxiliaries and other item (if required)**

- Top cover drainage system
- Oil pressure unit – complete with oil tank, 2 nos. of OPU pump – motor set, pressure accumulator, operating system, control and instruments
- Guide apparatus for movement of guide vanes
- Oil leakage unit
- Oil cooling unit
- Turbine guide bearing with coolers
- Shaft gland seal
- Governor, speed signal generator, over speed trip device
- All parts and accessories required to make a complete operating unit for controlling and regulating the speed of the turbine in conformity with performance characteristics.
- Oil for governor, lubricating oil and grease for flushing and first filling with 20% extra quantity.

### **3.3 Design Conditions**

#### **3.3.1 Project arrangements**

It should contain detailed description of project with general arrangement drawings of powerhouse and water ways at the high and low pressure side such as channels, galleries, penstocks, surge tank, valves / gates, etc. The data should be clear so that bidder may be aware of physical conditions that may affect detailed design.

#### **3.3.2 Hydraulic conditions**

- Maximum water level u/s (m)
- Maximum tail water level (m)
- Minimum tail water level (m)
- Maximum gross head (static) in m
- Maximum net head (m)
- Minimum net head (m)
- Rated head (design) (m)
- Discharge (Q) maximum (cumec)
- Discharge (Q) minimum (cumec)
- Discharge (Q) normal (cumec)
- Range of water temperature (°C)
- Water quality analysis (chemical, corrosive nature, biological, suspended solids)
- Range of ambient temperatures and humidity (tropical environment or extreme cold need to be clearly mentioned)

### 3.3.3 Specified conditions

- Models of operation
  - Base load or peaking
  - Anticipated number of start – stop per year
  - Capacity factor of power plant
  - Special operating features e.g. synchronous condenser, spinning reserve, isolated, black starting, draining through turbine, etc.,
- Rated output at rated discharge and rated (kW) head
- Speed
- Direction of rotation clockwise or anti clock wise viewing from generator towards turbine.

### 3.3.4 Besides above following considerations are also important

#### (i) Sand erosion considerations

Risk of sand erosion may influence design and operation of hydro turbine. Technical specification should indicate the content of suspended solids, their type size and shapes. For this water samples should be drawn during rainy season periodically and petrographic analysis of silt contents must be got done.

#### (ii) Safety requirements

All parts of turbine shall be designed and constructed to safely withstand the maximum stresses during the normal running, run away, short circuit conditions or out of phase synchronization and brake application. The maximum unit stresses of the rotating parts shall not exceed  $2/3^{\text{rd}}$  of the yield point of the material. For other parts factor of safety based on yield point shall not be less than three in normal condition. For over load, short circuit condition, a factor of safety of 1.5 (one & half) on yield point shall be permitted.

## 3.4 Performance Guarantees and Liquidated Damages

**3.4.1** Maximum output and efficiency of turbine at design head shall be stated in guaranteed technical particulars of turbine and will be guaranteed by equipment supplier. The turbine shall be suitable for safe and efficient performance at part loads above 60% (sixty percent) of rated output with minimum head conditions.

Field test (as per IEC-60041-1991) shall form the final basis to establish fulfillment of guarantees of the turbine and for the purpose of liquidated damages and rejection of plant.

### 3.4.2 Weighted average efficiency

The weighting factors i.e.  $k_1, k_2, k_3, k_4$  etc for each load case should be proportional to energy production at that particular load. The weighted average efficiency formula with weighted factor is to be given here in the following form which is a typical example, the weighting factor “ $k$ ” is to be taken as per actual discharges of the stream/ river of the actual project:

$\eta_T (AV) = k_1 \eta_{T110} + k_2 \eta_{T100} + k_3 \eta_{T80} + k_4 \eta_{T60}$   
 where :  $k_1 + k_2 + k_3 + \dots + k_n = 1$   
 and : for example if a plant as per availability of discharge (flow duration curve) is able to run.

- at 110% load for 10% of total running hours for financial service life
- at 100% load for 60% of total running hours for financial service life
- at 80% load for 20% of total running hours for financial service life
- at 60% load for 10% of total running hours for financial service life

then :  $k_1 = 0.1, k_2 = 0.6, k_3 = 0.20, k_4 = 0.1,$   
 and :  $\eta_{T(AV)} = 0.1\eta_{T110} + 0.6 \eta_{T100} + 0.20 \eta_{T80} + 0.1\eta_{T60}$   
 $\eta_{T(AV)}$  = weighted average efficiency of turbine

$\eta_{T110}, \eta_{T100}, \eta_{T80}, \eta_{T60},$  = Efficiency at 110%, 100%, 80% & 60% of rated output at designed head.

**Note:** Above percentages may vary as per requirement of customer

### 3.4.3 Bid evaluation

For evaluation purposes, with each 0.1% decrease of the weighted average efficiency from a given base (highest weighted average efficiency offered by any tenders) the tender price would be increased by the value of energy lost on account of less efficiency. The unit value of energy would have reasonable relationship to the energy loss and the subsequent revenue decrease over the assumed financial service life of the machine.

The basis for selection of the offer will be overall economy to the purchaser considering powerhouse civil works, values of efficiency, prices of matching generator and power house auxiliaries etc. The speed and setting of the turbine and its design shall be such as to result in the most optimum generating unit at the least cost.

### 3.4.4 Output and efficiency tests

Test as prescribed in IEC-60041-1991 shall be conducted at different heads and guide vane openings to determine guaranteed efficiency parameters. Any deviation from provisions of tests in IEC-60041-1991 should be clearly stated in the offer. Bidders shall furnish details of test methods, agency which will conduct the test, provisions to be made for field testing, calibration of instruments for purposes of test and all other relevant details. Contractor shall be under obligation to accept these tests for the purpose of liquidated damages.

Purchaser reserves the right to appoint the contractor or any independent agency or agency recommended by the contractor for conducting these tests, cost of which will be borne by the contractor, in any case.

### 3.4.5 Penalty for short fall in weighted average efficiency and output

Penalty shall be applicable at the rate in percentage, to be decided by the Project Authorities (generally 0.5% of total unit price of turbine (including governor) for each one tenth of one percent by which test figure is less than corresponding guaranteed figure. The penalty for short fall in output in kW shall be calculated separately and total penalty will be

sum of two. However, total amount penalty shall not exceed mutually agreed percentage (say 10%) of the total unit price of turbine or with no upper limit.

#### **3.4.6 Rejection limit**

The purchaser has the right to reject the turbine if the test value of either weighted average efficiency or rated output is less than the corresponding guaranteed value by 2 (two) percent or more after allowing agreed tolerance in computation of efficiency.

#### **3.4.7 Cavitation guarantee**

The runner should be guaranteed against excessive pitting caused by cavitation for 18 months from the date of commissioning or 8000 hrs of operation whichever is earlier. Excessive pitting shall be defined as the removal of metal from the runner of weight '(w)' where

$$w = 0.15 D^2$$

where 'D' is the discharge diameter of runner and 'w' is the weight in kg checking of this guarantee shall be as per IEC:61609-1999

In case cavitation pitting exceeds guaranteed value the turbine supplier will take corrective measures at his own cost. Turbine after modification etc. shall be subject to cavitation guarantee as per original equipment.

#### **3.4.8 Critical & plant sigma**

Values of critical sigma as determined from cavitation model tests as per IEC 60193-1999 and shall be given in the form of curves for different heads of operation. Plant sigma curves as recommended by manufacturer shall also be plotted on it clearly to show the safety margin available.

#### **3.4.9 Vibration and noise level**

The turbine design shall ensure smooth and quiet operation with low vibrations, pressure pulsations, power fluctuations and noise.

The vibration amplitude at shaft shall not exceed the values specified in ISO-7919 (part-I) and ISO-3945 or VDI 2056 and VDI 2059 when measured with instrument 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 machine hall.

#### **3.4.10 Runaway speed**

The maximum runaway speed shall be stated and guaranteed by the supplier. For generating units above 3 MW, all rotating parts and bearings shall be capable of withstanding the runaway speed attained with guide vanes fully open and the generator disconnected and unexcited and with gross maximum head on turbine, without any damage to its parts for every such occurrence for 30 minutes provided that the cooling arrangements are functional

and for 15 minutes without cooling water. For generating units below 3 MW, all parts shall be capable of withstanding run away speed continuously.

#### **3.4.11 Speed rise, pressure rise and inertia**

The moment of inertia of the generating unit and closing time of guide vanes should be so selected that maximum momentary speed rise of unit shall not exceed 45% of normal speed and pressure rise shall not exceed 25-35% of maximum head. The turbine manufacturer shall coordinate with the generator manufacture to achieve desired fly wheel effect.

#### **3.4.12 Model test**

The design of turbine offered shall be based on a previous homologous model test carried out as per IEC test code publication no 60193-1999& 60193A-1999 and relevant Indian Standards. The tenderer should provide sufficient details of model test to the purchaser so as to ensure surety that such test has been carried out.

Model test results shall be subject to purchaser's approval. Manufacturing of prototype turbine should be commenced after approval of test results.

### **3.5 General Arrangement and Construction**

Normally Francis Turbine consists of the following major components

- (i) Embedded components
- (ii) Static removable components
- (iii) Rotating components

#### **3.5.1 Embedded components**

Embedded components of Francis turbine are as follows:

- (i) Spiral casing ( vertical only)
- (ii) Stay ring ( vertical only)
- (iii) Foundation ring or lower ring( vertical only)
- (iv) Draft tube and draft tube liner
- (v) Pit liner( vertical only)

##### **3.5.1.1 Spiral casing**

A general description should be given, which should cover design data viz., design pressure, test pressure, internal pressure during embedment and material to be used for manufacturing quoting relevant standards and general data giving location, size and type of inlet connection, location, size of spiral drain valve, man hole for maintenance and parts transportation.

##### **3.5.1.2 Stay ring**

A general description should be given which should cover weight of concrete generator and vertical load supported by stay ring, all loads & pressure coming over spiral

casing, material for manufacturing quoting relevant Indian Standard, tolerance on location in plan and elevation, details of test connections, transportation and handling. For small machines up to 5 MW spiral casing and stay ring shall be fabricated and machined in manufacturing unit and shall be transported in one or two parts to site.

#### **3.5.1.3 Foundation ring**

Brief description of foundation ring along with special loading conditions material for manufacturing, transportation, site handling limitation, tolerances for location in plan and elevation, location, size, type and other details of connections (draft tube aeration, test etc.) Transportation support and erection handling device, should be given here.

#### **3.5.1.4 Draft tube and draft tube liner**

Brief description of draft tube along with maximum design pressure for liner, maximum allowable pressure pulsation amplitude, type of material for manufacturing, maximum thickness of liner plate, transportation and handling, dimensional tolerances, location and other details of downstream limit, details of inspection windows, maintenance platform and lifting devices should be narrated here.

Besides above, location, size and details of connections (e.g. man holes, draft tube drains, aeration piping, draft tube water level controls, indication and test devices etc.) should also be given.

Details of permanent and temporary erection support, handling devices (anchor, tie rods supports etc) should be narrated in this clause.

#### **3.5.1.5 Pit liner**

Brief description of pit liner along with minimum thickness, external pressure, external rib arrangement, material for manufacturing, servomotor support arrangement, support for turbine pit hoist, hoist diameter should be matching with inner bore clearance of stator, elevation of top of pits liner, details of turbine pit access, location of guide vane servomotor support flanges, location size and details of pipe connections (for turbine pit drainage, bearing cooling water, bearing lubricating oil, service air, central grease lubrication system etc), transportation support and erection handling devices.

### **3.5.2 Technical specification for stationary / removable components**

General description of distributor assembly should be given in this para.

#### **3.5.2.1 Head cover and bottom ring**

Short description of the head cover and bottom ring should be narrated in this para eg both head cover should be removable for maintenance, guide vane bushes should be replaceable without dismantling head cover and bottom ring.

Besides material for manufacturing, pit drainage arrangement location of guide bearing, arrangement of shaft seal stationary wear ring & material, guide bearing support

system, with access for maintenance of guide bearing and shaft seal, details of guide vane bearing housing and bushing with material and special features (dirt seals etc.).

### **3.5.2.2 Guide vanes**

Brief description of guide vane along with type material (resistant to corrosion erosion and cavitation), hydraulic torque characteristic, guide vane to guide vane sealing arrangement.

Type of material for guide vane bushes and material for guide vane stem seals should also be given.

### **3.5.3 Technical specification for guide vane regulating apparatus**

Brief description of guide vane regulating system.

#### **3.5.3.1 Servomotor**

Preferred location in turbine pit, type of material for manufacturing, maximum and minimum allowable operating pressure (if governor supplied separately), test pressure, opening and closing time, arrangement of seals, other requirements if any, for ease of operation and maintenance should be narrated in this para.

#### **3.5.3.2 Connecting rods**

Type of material, preferred arrangement and minimum bushing requirement should be mentioned.

#### **3.5.3.3 Regulating ring**

Brief description of arrangement of regulating ring, type of material for manufacturing, support requirement on head cover should be given here.

#### **3.5.3.4 Guide vane linkage**

Brief description of arrangement of GV linkage, type of material and individual adjustment on each guide vane in closed position to be narrated.

#### **3.5.3.5 Locking devices**

Describe in brief preferred arrangement automatic or manual, “closed” or “open” position, lock position detection, lock position annunciation.

### **3.5.4 Technical Specification of rotating parts, guide bearings and seals**

#### **3.5.4.1 Runner**

The runner shall be of 13/4 chromium-nickel stainless steel. The composition of the material and the source of runner casting shall be stated in the tender. The runner shall be cast integrally of stainless steel. The runner will be a one-piece construction. The runner will have

adequate number of blades which shall be polished and ground smooth and shall be free from roughness, cracks, high spots, etc. The finished machine and ground runner shall be dynamically balanced in the works before dispatch. For runner of diameter more than 1000 mm. renewable wearing rings (Labyrinths) shall be provided.

#### **3.5.4.2 Main shaft**

The turbine shaft shall be forged carbon steel or alloy steel conforming to IS or other equivalent international standards. Wherever the flanges are integral with the shaft, the same should conform to American standard ANSI-49.1, 1967. For long larger size shafts, tubular construction of proven design will also be considered. The turbine shaft shall be connected to the runner on one side and to the gear box/flywheel / generator shaft on the other side. It shall be of ample size to transmit torque at rated speed without excessive vibration or any distortion. Coupling guard shall be supplied by turbine manufacturer.

A renewable and removable sleeve of stainless steel shall be provided wherever the shaft passes through a shaft seal or a gland.

The turbine manufacturer shall co-ordinate and co-operate with the generator manufacturer for proper design and construction. The final alignment of the shaft at site shall be the responsibility of the generator manufacturer.

#### **3.5.4.3 Turbine guide bearing**

The turbine bearings can be:

- (a) The pad type or sleeve type with Babbitt lining, oil/grease lubricated either self-lubrication or forced lubrication type.
- (b) Anti-friction ball, roller bearings, oil or grease lubricated.
- (c) Water lubricated pad type. In this case the shaft shall have stainless steel removable sleeve lining where it passes through the bearing.

The bearings shall be guaranteed for a minimum continuous operation of 100,000 (one hundred thousand) hours and the design and performance shall be well proven and established.

The turbine shall be provided with adequate number of bearings. The bearings of turbines 3 MW and above rating, shall be designed to withstand operation at maximum runaway conditions with cooling water supply on (if cooling water is provided) for a period of not less than 30 minutes and also for operation at runaway speed without cooling water supply for 15 minutes. The bearing of turbines below 3 MW rating shall be designed to withstand condition of max. run away speed continuously with or without cooling water supply. The bearings shall be provided with a dial type or resistance type thermometer and a pressure gauge with provision for alarm annunciation/shut down on excessive bearing temperatures. The number and type of bearings shall be stated in the tender.

#### **3.5.4.4 Main shaft seal**

The shaft gland shall be of the stuffing box/carbon ring type with self-lubricated packing and lantern ring. Any other suitable type of shaft gland will also be considered. The gland shall effectively prevent leakage of water along the shaft under all operating conditions

and at standstill and prevent entry of air. In case the location of the gland is below maximum tail water level, an inflatable rubber seal shall be provided for attending the main gland without dewatering the draft tube. A stainless steel sleeve shall be provided on the shaft where it passes through the gland.

Arrangement for providing clean water supply to the gland, if required, shall be made by the contractor.

#### **3.5.4.5 Repair (maintenance) seal**

General description, material for housing fabrication, material for active sealing, actuation system (e.g. by compressed air etc) should be given.

### **3.5.5 Technical specification for miscellaneous components**

#### **3.5.5.1 Walkways, access platform and stairs**

It should include, walkway, and railing in turbine pit and its access for runner inspection platform. Description of minimum requirement, loading requirements, applicable safety codes, should also be given.

#### **3.5.5.2 Lifting devices**

Requirement of lifting devices for runner and shaft, guide vanes, regulating mechanism, head cover, servomotors guide vane operating mechanism in pit, bottom cover, guide bearing & coupling bolts etc. should be narrated.

#### **3.5.5.3 Special tools & tackles**

Requirement of special tools & tackles for loosening and tightening of coupling bolts, dismantling and assembly of overload protection device, guide vane levers, special wrenches, jack, shaft lifting device, slings, templates for runner and guide vane repairs etc. should be mentioned in this clause.

#### **3.5.5.4 Standard tools**

Complete new set of standard tools for maintenance of turbine should be given.

#### **3.5.5.5 Turbine pit hoist**

This is required for maintenance of guide bearing, guide vanes operating mechanism and top cover drain pump motor etc.

#### **3.5.5.6 Name plate**

Minimum data to be given on name plate, its size and location should be given.

### **3.5.6 Technical specification of auxiliaries**

Brief description of bearing lubrication system, guide vanes lubrication system, top cover drainage system, pressure relief valves, air admission system, lubrication of regulating mechanism, control indication and annunciation, should be given in this section.

### **3.5.7 Technical specification for instrumentation control and safety devices**

Brief description of instrumentation, control and safety devices preferred should be narrated e.g. unit start interlocks, low flow bearing cooling, low flow shaft sealing lubrication etc., indication for bearing oil level, bearing temperatures and protection requirement viz., bearing temperature high, shaft seal temperature high,.

Thus each turbine shall be provided with complete set of instruments, gauge, control and protection devices at appropriate place to monitor the condition of unit during normal running and emergencies.

### **3.6 Spare Parts**

List of spare parts required for five years trouble free operation of the plant should be given and these should be manufactured with the main plant and delivered with turbine components. Minimum requirement of spares should include, bearing shell or set of pads, set of guide vane bushings, shaft seal wear components complete set of seals, o-rings, gaskets for dismantling and reassembly, set of head cover studs, other studs, nuts, bolts etc.

Tenders should be requested to submit their list of recommended spares and price with the tenders.

### **3.7 Shop Assembly and Test**

Bidder should be asked to submit quality assurance plan indicating test to be performed and witnessed by the purchaser and their acceptance criteria. This quality plan should be approved by the purchaser after due diligence. Quality assurance plan should essentially include the following:

- (i) All assemblies and subassemblies should be properly match marked and dowelled to ensure quick assembly at site
- (ii) Static balancing of runner
- (iii) Dynamic balancing of runner up to 1 m throat diameter
- (iv) Non destructive test of welded joints
- (v) Performance test for individual auxiliary equipment
- (vi) All motors, pumps, compressors to be tested as per relevant Indian Standards
- (vii) Routine test reports of all bought out items shall be finished before dispatch for approval
- (viii) Guide vanes and guide operating mechanism shall be assembled in shop to ensure proper clearance between end faces of guide vanes, clearance between consecutive guide vanes in fully closed position at three places, opening between consecutive guide vanes at 50%, 75% and 100% open position at three places, minimum force to move regulating ring with guide vanes freely
- (ix) Hydraulic testing of servomotors, stroke checking, oil leakage checking
- (x) Material test of important components such as runner blades, guide vanes turbine shaft, guide pads, bushes, piston rods and other components shall be carried out as per agreed plan.

### **3.8 Site Installation Testing and Commissioning**

The bidder should be asked to prepare erection procedure and check points at every stage as to set elevation and centerline as also form of different components of turbine to be installed at site. The procedure should contain full cross referencing to turbine drawings and to location of measurement points and should become a part of maintenance manual, erection tolerances should follow Indian and International practices or standards.

The procedure should give limit for location of embedded parts which need to be verified and monitored before pouring of concrete.

The procedure should also specify measurement records to be made during installation and setting of components for example relative location, clearances, elevation, rotational checks etc. It should cover requirements of connected generators.

#### **3.8.1 Field acceptance tests**

The field acceptance tests shall be carried out as per IEC60041-1991 for field acceptance tests of hydraulic turbines. The arrangements for these tests including testing device shall be within scope of the contractor's work.

Tests during Erection

- (i) 25% radiographic testing of all welded seams of spiral case and inlet pipe
  - (ii) Pressure testing of spiral casing measurements of clearances of labyrinth seals, guide bearing pads
  - (iii) Measurement of guide vane gaps
- Commissioning Tests

Once erection is complete following tests are required to be carried out

- (i) Relation between servomotor stroke and guide vane opening
- (ii) Determination of GV opening at no load
- (iii) Rotational checks for establishing alignment of shaft
- (iv) GV opening/ closing time by dry stroking
- (v) Operation of unit at no load – check run out of rotating parts, behavior of various bearings, setting over speed trip device
- (vi) Operation of unit at part loads and full load – check run out of rotating parts, behavior of various bearings, check vibration pulsation and noise
- (vii) Output and guide vane opening relationship
- (viii) Load rejection tests at 50%, 75% and 100% load
- (ix) Check proper operation of all turbine auxiliaries
- (x) Tests for meeting performance guarantee

#### **3.8.2 Inspection for cavitation pitting**

It is to be ensured that operating records during guarantee period are properly maintained. It is also to be verified that machines are operated within specified range of output, head and discharge.

After specified period of running of machine joint inspection is to be carried for cavitation pitting and establishing that cavitation is within limits and the turbine supplied meets the cavitation guarantee.

## **4.0 TECHNICAL SPECIFICATIONS FOR KAPLAN AND PROPELLER TURBINE**

### **4.1 Scope**

The scope under this section should include design, material selection, manufacture, shop assembly and testing, transportation and delivery to site, insurance, storage at site installation, commissioning, field acceptances test, warrantee and other services as specified or required.

### **4.2 Detailed list of major items should be as follows**

- (i). Turbine
  - Type of turbine - Kaplan / Propeller (complete with all embedded, static removable parts and rotating parts)
  - No. of units - As per specific project
  - Shaft - Vertical
  - Rated power at rated head and rated discharge - kW
- (ii). Turbine model testing
- (iii). Tools, slings, handling devices for assembly and maintenance of turbine
- (iv). Transportation and delivery at site
- (v). Site installation, commissioning and acceptance tests
- (vi). Insurance for transit, storage at site, erection, testing and commissioning
- (vii). Preparation and submission of operation and maintenance manual and training of O&M staff in optimum use of these manuals
- (viii). Set of spare parts for five years trouble free operation. A schedule of spare parts is required to be annexed.

#### **4.2.1 Auxiliaries and other items**

- (i) Top cover drainage system
- (ii) Oil pressure unit complete with oil tank, 2 nos OPU pumps-motor sets, pressure accumulator complete with operating system, control and instruments.
- (iii) Guide apparatus for movement of guide vanes & runner blades movement mechanism
- (iv) Oil leakage unit
- (v) Oil cooling unit
- (vi) Turbine guide bearing with cooling arrangement
- (vii) Shaft gland seal
- (viii) Governor, speed signal generator, over speed trip device
- (ix) All parts and accessories to make a complete operating unit for controlling and regulating the speed of the turbine in conformity with performance characteristic.
- (x) Oil for governor, lubricating oil and grease for flushing and first filling with 20% extra quantity.

### 4.3 Design Conditions

#### 4.3.1 Project arrangement

It should contain detailed description of project with general arrangement drawings of powerhouse and water ways at the high and low pressure side such as channels, galleries, penstocks, valves / gates, etc. The data should be clear so that bidder may be aware of physical conditions that may affect detailed design.

#### 4.3.2 Hydraulic conditions

- (i). Maximum water level u/s (m)
- (ii). Maximum tail water level (m)
- (iii). Minimum tail water level (m)
- (iv). Maximum gross head (static) in m
- (v). Maximum net head (m)
- (vi). Minimum net head (m)
- (vii). Rated head (Design) (m)
- (viii). Discharge (Q) 

Maximum	(cumec)
Minimum	(cumec)
Normal	(cumec)
- (ix). Range of water temperature ( $^{\circ}$  c)
- (x). Water quality analysis  
(Chemical, corrosive nature, biological, suspended solids)
- (xi). Range of ambient temperatures and humidity (tropical environment or extreme cold need to be clearly mentioned)

#### 4.3.3 Specified conditions

- (i). Modes of operation
  - (a) Base load or peaking
  - (b) Anticipated numbers of start-stop per year
  - (c) Capacity factor of power plant special operating features e.g. Synchronous condenser spinning reserve, isolated, black starting draining through turbine, etc.
- (ii). Rated output at rated discharge and rated head (kW)
- (iii). Speed output at rated discharge and rated head (rpm)
- (iv). Direction of rotation clockwise and anticlockwise viewing from generator side

#### 4.3.4 Besides above following considerations are also important

- (i) **Sand erosion considerations**  
Risk of sand erosion may influence design and operation of hydro-turbine. Technical specification should indicate the content of suspended solids their type, size and shapes. For this water samples should be drawn during rainy season periodically and petrographic analysis of silt contents must be got done.

(ii) **Safety requirements**

All parts of turbine shall be designed and constructed to safely with stand the maximum stresses during the normal running, runaway, short circuit conditions or out of phase synchronization and brake application. The maximum unit stresses of the rotating parts shall not exceed 2/3<sup>rd</sup> of the yield point of the material. For other parts factor of safety based on yield point shall not be less than three in normal condition. For over load short circuit condition, a factor of safety of 1.5 (one & half) on yield point shall be permitted.

#### 4.4 Performance Guarantees and Liquidated Damages

Maximum output and efficiency of turbine at design head shall be stated in Guaranteed Technical Particular of turbine and will be guaranteed by equipment supplier. The turbine shall be suitable for safe and efficient performance at part loads above 40% (forty percent) of rated output with minimum head conditions.

Field test (as per IEC-60041-1991) shall form the final basis to establish fulfillment of guarantees of the turbine and for the purpose of liquidated damage and rejection of plant.

##### 4.4.1 Weighted average efficiency

The weighting factors i.e.  $k_1, k_2, k_3, k_4$  etc for each load case should be proportional to energy production at that particular load. The weighted average efficiency formula with weighted factor is to be given here in the following form which is a typical example, the weighting factor “ $k$ ” is to be taken as per actual discharges of the stream/ river of the actual project:

$$\eta_T (AV) = k_1 \eta_{T110} + k_2 \eta_{T100} + k_3 \eta_{T80} + k_4 \eta_{T60} + k_5 \eta_{T40}$$

where :  $k_1 + k_2 + k_3 + \dots + k_n = 1$

and : for example if a plant as per availability of (discharge flow duration curve) is able to run.

- a) at 110% load for 10% of total running hours for financial service life
- b) at 100% load for 50% of total running hours for financial service life
- c) at 80% load for 25% of total running hours for financial service life
- d) at 60% load for 10% of total running hours for financial service life
- e) at 40% load for 5% of total running hours for financial service life

then :  $k_1 = 0.1, k_2 = 0.5, k_3 = 0.25, k_4 = 0.1, k_5 = 0.05$

and :  $\eta_{T(AV)} = 0.1\eta_{T110} + 0.5 \eta_{T100} + 0.25 \eta_{T80} + 0.1\eta_{T60} + 0.05 \eta_{T40}$   
 $\eta_{T(AV)}$  = weighted average efficiency of turbine

$\eta_{T110}, \eta_{T100}, \eta_{T80}, \eta_{T60}, \eta_{T40}$  = Efficiency at 110%, 100%, 80%, 60% & 40% of rated output at designed head.

#### **4.4.2 Bid Evaluation**

For evaluation purposes, with each 0.1% decrease of the weighted average efficiency from a given base (highest weighted average efficiency offered by any tenders) the tender price would be increased by the value of energy lost on account of less efficiency. The unit value of energy would have reasonable relationship to the energy loss and the subsequent revenue decrease over the assumed financial service life of the machine.

The basis for selection of the offer will be overall economy to the purchaser considering powerhouse civil works, values of efficiency, prices of matching generator and power house auxiliaries etc. The speed and setting of the turbine and its design shall be such as to result in the most optimum generating unit at the least cost.

#### **4.4.3 Output and efficiency tests**

Test as prescribed in IEC-60041-1991 shall be conducted at different heads and guide vane openings to determine guaranteed efficiency parameters. Any deviation from provisions of tests in IEC-60041-1991 should be clearly stated in the offer. Bidders shall furnish details of test methods, agency which will conduct the test, provisions to be made for field testing, calibration of instruments for purposes of test and all other relevant details. Contractor shall be under obligation to accept these tests for the purpose of liquidated damages.

Purchaser reserves the right to appoint the contractor or any independent agency or agency recommended by the contractor for conducting these tests, cost of which will be borne by the contractor, in any case.

#### **4.4.4 Penalty for Short Fall in Weighted Average Efficiency and Output**

Penalty shall be applicable at the rate of ½ (half) percent of total unit price of turbine for each one tenth of one percent by which test figure is less than corresponding guaranteed figure. The penalty for short fall in output in kW shall be calculated separately and total penalty will be sum of two. However, total amount penalty shall not exceed mutually agreed percentage (say 10%) of the total unit price of turbine or with no upper limit.

#### **4.4.5 Rejection Limit**

The purchaser has the right to reject the turbine if the test value of either weighted average efficiency or rated output is less than the corresponding guaranteed value by 2 (two) percent or more after allowing agreed tolerance in computation of efficiency.

#### **4.4.6 Cavitation guarantee**

The runner should be guaranteed against excessive pitting caused by cavitation for 18 months from the date of commissioning or 8000 hrs of operation whichever is earlier. Excessive pitting shall be defined as the removal of metal from the runner of weight '(w)' where

$$w = 0.15 D^2$$

where 'D' is the discharge diameter of runner and 'w' is the weight in kg checking of this guarantee shall be as per IEC 61609-1991

In case cavitation pitting exceeds guaranteed value the turbine supplier will take corrective measures at his own cost. Turbine after modification etc. shall be subject to cavitation guarantee as per original equipment.

#### **4.4.7 Critical & plant sigma**

Values of critical sigma as determined from cavitation model tests as per IEC 60193A and shall be given in the form of curves for different heads of operation. Plant sigma curves as recommended by manufacturer shall also be plotted on it clearly to show the safety margin available.

#### **4.4.8 Vibration and noise level**

The turbine design shall ensure smooth and quiet operation with low vibrations, pressure pulsations, power fluctuations and noise.

The vibration amplitude at shaft shall not exceed the values specified in ISO-7919 (part-I) and ISO-3945 or VDI 2056 and VDI 2059 when measured with instrument 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 machine hall.

#### **4.4.9 Runaway speed**

The maximum runaway speed shall be stated and guaranteed by the supplier. For generating units above 3 Mw, all rotating parts and bearings shall be capable of with standing the runaway speed attained with guide vanes fully open and the generator disconnected and unexcited and with gross maximum head on turbine, without any damage to its parts for every such occurrence for 30 min. provided that the cooling arrangements are functional and for 15 minutes without cooling water supply. For generating units below 3 MW, all parts shall be capable of withstanding run away speed continuously without cooling water supply.

#### **4.4.10 Speed rise, pressure rise and inertia**

The moment of inertia of the generating unit and closing time of guide vanes should be so selected that maximum momentary speed rise of unit shall not exceed 45% of normal speed and pressure rise shall not exceed 25-35% of maximum head. The turbine manufacturer shall coordinate with the generator manufacture to achieve desired fly wheel effect.

#### **4.4.11 Model test**

The design of turbine offered shall be based on a previous homologous model test carried out as per IEC test code publication no 60193-1999&60193A-1991 and relevant Indian Standards. The tenderer should provide sufficient details of model test to the purchaser so as to ensure surety that such test has been carried out.

Model test results shall be subject to purchaser's approval. Manufacturing of prototype turbine should be commenced after approval of test results.

## **4.5 General Arrangement and Construction**

Normally Francis Turbine consists of the following major components

- (i). Embedded components
- (ii). Static removable components
- (iii). Rotating components

### **4.5.1 Embedded components**

Embedded components of Kaplan turbine are as follows:

- (i). Spiral casing
- (ii). Stay ring
- (iii). Runner chamber
- (iv). Draft tube and draft tube liner
- (v). Pit liner

#### **4.5.1.1 Spiral casing and stay ring**

The spiral casing shall be fabricated from welded steel plate/mild steel plates and shall have suitable sections for ease of shipment and to be within transport limitation. The spiral case shall be designed to withstand maximum water pressure including water hammer and shall be complete with anchors, supports, sole plates, turn buckles, hold-down rods, all types of clamps, etc. The stay ring shall be low alloy cast steel or of welded plate steel and shall be in suitable number of sections. The assembled stay ring shall be suitable for welding on to the spiral casing.

The spiral casing shall be provided with two pairs of pressure taps with manifold measurements of differential pressure to calculate relative discharge for index test on the turbine.

#### **4.5.1.2 Runner chamber**

Brief description of runner chamber along with special loading conditions, material for manufacturing, transportation, site handling limitation, tolerances for location in plan and elevation, location, size, type and other details of connections, transportation, erection support and handling device, should be given here.

#### **4.5.1.3 Draft tube and draft tube liner**

Brief description of draft tube along with, maximum design pressure for liner maximum allowable pressure pulsation amplitude, type of material for manufacturing, maximum thickness of liner plate transportation and handling, dimensional tolerances location and other details of downstream limit, details of inspection windows, maintenance platform and lifting devices should be narrated here.

Besides above location, size and details of connections (e.g. spiral case, draft tube drains, aeration piping, draft tube water level controls, indication and test devices etc.) should also be given.

Details of permanent and temporary erection support, handling devices (anchor, tie rods supports etc) should be narrated in this clause.

#### **4.5.1.4 Pit liner**

Brief description of pit liner along with external pressure minimum thickness, external pressure, minimum thickness, external rib arrangement, material for manufacturing, servomotor support arrangement, support for turbine pit hoist, hoist track diameter which should be matching with inner bore clearance of stator, elevation of top of pits liner, details of turbine pit access, location of guide vane servomotor support flanges, location size and details of pipe connections (for turbine pit drainage, bearing cooling water bearing lubricating oil, servomotor service air, central grease lubrication system etc), transportation support and erection handing devices.

#### **4.5.2 Technical specification for stationary / removable components**

General description of distributor assembly should be given in this paragraph.

##### **4.5.2.1 Head cover and bottom ring**

Short description of the head cover and bottom ring should be narrated in this paragraph e.g. head cover should be removable for maintenance, guide vane bushes should be replaceable without dismantling head cover and bottom ring.

Besides material for manufacturing, pit drainage arrangement location of guide bearing, arrangement of shaft seal stationary wear ring & material, guide bearing support system, with access for maintenance of guide bearing and shaft seal, details of guide vane bearing housing and bushing with material and special features (dirt seals etc.).

##### **4.5.2.2 Guide vanes**

Brief description of guide vane along with type material (resistant to corrosion erosion and cavitation), hydraulic torque characteristic, guide vane to guide vane sealing arrangement. Type of material for guide vane bushes and material for guide vane stem seals should also be given.

#### **4.5.3 Technical specification for guide vane regulating apparatus**

Brief description of guide vane regulating system:

##### **4.5.3.1 Servomotor**

Preferred location in turbine pit, type of material for manufacturing, maximum and minimum allowable operating pressure (if governor supplied separately), test pressure, opening and closing time, arrangement of seals, other requirements if any, for ease of operation and maintenance should be narrated in this para.

##### **4.5.3.2 Connecting rods**

Type of material, preferred arrangement and minimum bushing requirement should be mentioned.

#### **4.5.3.3 Regulating ring**

Brief description of arrangement of regulating ring, type of material for manufacturing, support requirement on head cover should be given here.

#### **4.5.3.4 Guide vane linkage**

Brief description of arrangement of GV linkage, type of material and individual adjustment on each guide vane in closed position to be narrated.

#### **4.5.3.5 Locking devices**

Describe in brief preferred arrangement of automatic or manual locking, requirement for lock position detection and lock position annunciation.

### **4.5.4 Technical specification of rotating parts, guide bearings and seals**

#### **4.5.4.1 Runner**

- (i) Brief description of runner along with type material for manufacturing various runner components quoting relevant standard (resistant to corrosion, erosion and cavitation) support of runner and shaft during erection and subsequent maintenance, requirement of static balancing should be given in this paragraph.
- (ii) Runner blades  
Runner blades shall be manufactured from 13 / 4 Cr Ni stainless steel. Runner water passage shape and finish of runner blades is important factor in reducing cavitation damages as such during manufacturing proper quality should be ensured.
- (iii) Runner hub, cone, blade seals and bearings  
Brief description of runner hub, cone, blade seals, bearings and type of material for their manufacturing quoting relevant Indian Standard.

#### **4.5.4.2 Runner blade regulating mechanism**

- (i) Blade servomotor  
General description, location (shaft, hub), material for manufacturing pressure testing, maximum and minimum allowable operating pressure, other requirement regarding O&M should be narrated.
- (ii) Runner blade trunion  
Brief description and material for manufacturing.
- (iii) Blade lever & links  
Brief description, type of material to be used for manufacturing, minimum bushing requirement should be given.
- (iv) Oil header  
Brief description, material type, piping connections, minimum bushing requirement
- (v) Rotating seal rings  
Brief description covering type material which should be compatible to the material used on stationary wearing rings as also design i.e. removable or one piece with runner, should be given in this paragraph.

#### **4.5.4.3 Main shaft**

##### **4.5.4.3.1 Shaft and coupling**

The turbine shaft shall be forged carbon steel or alloy steel conforming to IS or other equivalent international standards. Wherever the flanges are integral with the shaft, the same should conform to American standard ANSI- 49.1, 1967. Shaft shall be of tubular construction to pass runner oil pipe lines. The turbine shaft shall be connected to the runner on one side and to the gear box/flywheel / generator shaft on the other side. It shall be of ample size to transmit torque at rated speed without excessive vibration or any distortion.

A renewable and removable sleeve of stainless steel shall be provided wherever the shaft passes through a shaft seal or a gland.

The turbine manufacturer shall co-ordinate and co-operate with the generator manufacturer for proper design and construction. The final alignment of the shaft at site shall be the responsibility of the generator manufacturer. Shaft coupling guard shall be supplied by turbine manufacturer

##### **4.5.4.4 Turbine guide bearing**

The turbine bearings can be:

Babbitt lined pad type or sleeve type or, oil/grease lubricated either self-lubrication or forced lubrication type.

Anti-friction ball, roller bearings, oil or grease lubricated.

Water lubricated pad type. In this case the shaft shall have stainless steel removable sleeve lining where it passes through the bearing.

The bearings shall be guaranteed for a minimum continuous operation of 100,000 (one hundred thousand) hours and the design and performance shall be well proven and established.

The turbine shall be provided with adequate number of bearings. The bearings shall be designed to withstand operation at maximum runaway conditions with cooling water supply on (if cooling water is provided) for a period of not less than 30 minutes and also for operation at runaway speed without cooling water supply for 15 minutes. The bearings shall be provided with a dial type or resistance type thermometer and a pressure gauge with provision for alarm annunciation/shut down on excessive bearing temperatures. The number and type of bearings shall be stated in the tender.

##### **4.5.4.5 Main shaft seal**

The shaft gland shall be of the stuffing box/carbon ring type with self-lubricated packing and lantern ring. Any other suitable type of shaft gland will also be considered. The gland shall effectively prevent leakage of water along the shaft under all operating conditions and at standstill and prevent entry of air. In case the location of the gland is below maximum tail water level, an inflatable rubber seal shall be provided for attending the main gland

without dewatering the draft tube. A stainless steel sleeve shall be provided on the shaft where it passes through the gland.

Arrangement for providing clean water supply to the gland, if required, shall be made by the contractor.

#### **4.5.4.6 Repair (maintenance) seal**

General description material for housing fabrication, material for active seal ring, actuation system (e.g. by compressed air etc.) be given.

### **4.5.5 Technical specifications for miscellaneous components**

#### **4.5.5.1 Walkways, access platform and stairs**

It should include walkway and railing in turbine pit and its access for runner inspection platform. Description of minimum requirement, loading requirements, applicable safety codes, should also be given.

#### **4.5.5.2 Lifting devices**

Requirement of lifting devices for runner and shaft, guide vanes, regulating mechanism, head cover, servomotors, guide vane operating mechanism in pit, bottom cover, guide bearing & coupling bolts etc. should be narrated.

#### **4.5.5.3 Special tools & tackles**

Requirement of special tools & tackles for loosening and tightening of coupling bolts, dismantling and assembly of overload protection device, guide vane levers, special wrenches, jacks, shaft lifting device slings and set of templates for repair of runner blades and guide vanes should be mentioned in this clause.

#### **4.5.5.4 Standard tools**

Complete new set of standard tools for maintenance of turbine should be given.

#### **4.5.5.5 Turbine pit hoist**

This is required for maintenance of guide bearing, guide vane operating mechanism and top cover drain pump motor etc.

#### **4.5.5.6 Name plate**

Minimum data to be given on name plate, its size and location should be given.

### **4.5.6 Technical specification of auxiliaries**

Brief description of bearing lubrication system, guide vanes lubrication system, top cover drainage system, air admission system, lubrication of regulating mechanism, control, indication and annunciation should be given in this section.

#### **4.5.7 Technical specification for instrumentation control and safety devices**

Brief description of instrumentation, control and safety devices preferred should be narrated e.g. unit start inter locks, low flow bearing cooling low flow shaft sealing lubrication etc., indication for bearing oil level, bearing temperatures and protection requirement viz., bearing temperature high.

Thus each turbine shall be provided with complete set of instruments, gauge, control and protection devices at appropriate place to monitor the condition of unit during normal running and emergencies.

#### **4.6 Spare Parts**

List of spare parts required for five years trouble free operation of the plant should be given and these should be manufactured with the main plant and delivered with turbine components. Minimum requirement of spares should include, bearing shell or set of pads, set of guide vane bushings, shaft seal wear components complete set of seals, o-rings gaskets for dismantling and reassembly set of head cover studs, other studs, nuts, bolts etc.

Tenderers should be requested to submit their list of recommended spares and price with the tender.

#### **4.7 Shop Assembly and Test**

Bidder should be asked to submit quality assurance plan indicating test to be performed and witnessed by the purchaser and their acceptance criteria. This quality plan should be approved by the purchaser after due diligence. Quality assurance plan should essentially include the following:

- (i). All assemblies and subassemblies marked and dowelled to ensure quick assembly at site
- (ii). Static balancing of runner
- (iii). Non destructive test of welded joints
- (iv). Performance test for individual auxiliary equipment
- (v). All motors, pumps, compressors to be tested at respective sub-supplier's works as per relevant Indian Standards
- (vi). Routine test reports of all bought out items shall be finished before dispatch for approval
- (vii). Guide vanes and guide operating mechanism shall be assembled in shop to ensure proper clearance between end faces of guide vanes, clearance between consecutive guide vanes in fully closed position at three places, opening between consecutive guide vanes at 50%, 75% and 100% open position at three places, minimum force to move regulating ring with guide vanes freely
- (viii). Runner, runner blade operating system should be assembled in shop and hydraulic pressure test should be performed to ensure proper sealing of runner blades and their proper opening and closing at required oil pressure is established
- (ix). Hydraulic testing of servomotors, stroke checking, oil leakage checking

- (x). Material test of important components such as runner blades, guide vanes, turbine shaft, guide pads, bushes, piston rods and other components shall be carried out as per agreed plan

#### **4.8 Site Installation Testing and Commissioning**

The bidder should be asked to prepare erection procedure and check points at every stage so as to set elevation and centerline as also form of different components of turbine to be installed at site. The procedure should contain full cross referencing to turbine drawing and to location of measurement points and should become a part of maintenance manual erection tolerances should follow Indian and International practices or standards.

The procedure should give limit for location of embedded parts which need to be verified and monitored before pouring of concrete.

The procedure should also specify measurement records to be made during installation and setting of components for example relative location, clearances, elevation, rotational checks etc. It should cover requirements of connected generators.

##### **4.8.1 Field acceptance test**

The field acceptance tests shall be carried out as per IEC 60041-1991 for field acceptance tests of hydraulic turbines. The arrangements for these tests including testing device shall be within scope of the contractor's work.

###### **4.8.1.1 Test during erection**

- (i) 25% radiographic testing of all welded seams of spiral casing
- (ii) Pressure testing of spiral casing
- (iii) Measurements of clearances of runner & runner chamber, guide bearing pads
- (iv) Measurement of guide vane gaps
- (v) Pressure testing of runner assembly in erection bay.

###### **4.8.1.2 Commissioning tests**

Once erection is complete following tests are required to be carried out

- (i). Relation between servomotor stroke and guide vane opening
- (ii). Determination of GV opening and runner blade opening at no load
- (iii). Rotational checks for establishing alignment of shaft
- (iv). (a) GV opening / closing time by dry stroking
- (v). Runner blade opening and closing time by dry stroking
- (vi). Relation between guide vane opening and runner blade opening
- (vii). Operation of unit at no load – check run out of rotating parts, behavior of various bearings, setting over speed trip device
- (viii). Operation of unit at part loads and full load – check run out of rotating parts behavior of various bearings, check vibration, pressure pulsation and noise
- (ix). Guide vane opening and runner blade opening at different loads
- (x). Load rejection tests at 50%, 75% and 100% load
- (xi). Check proper operation of all turbine auxiliaries
- (xii). Tests for meeting performance guarantee

### 4.8.1.3 Inspection for cavitation pitting

It is to be ensured that operating records during guarantee period are properly maintained. It is also to be verified that machines are operated within specified range of output head and discharge.

After specified period of running of machine joint inspection is to be carried for cavitation pitting and establishing that cavitation is within limits and the turbine supplied meets the cavitation guarantee.

## 5.0 TECHNICAL SPECIFICATIONS FOR PELTON/TURGO AND CROSSFLOW TURBINE

### 5.1 Scope

The scope of work under this section should include design, material selection, manufacture, shop assembly and testing, transportation and delivery to site, insurance, and storage at site, installation, commissioning, field acceptance tests, warranty and other services as specified or required.

#### 5.1.1 Detailed list of major items should be as follows

- a) Turbine
  - i. Type of turbine - Pelton / Turgo (complete with all embedded, static removable parts and rotating parts)
  - ii. No. of units - AS per specific project
  - iii. Shaft - Vertical /horizontal
  - iv. Rated power at rated head and rated discharge(kW) -
- b) Turbine model testing
- c) Tools, slings, handling devices for assembly and maintenance of turbine
- d) Transportation and delivery at site
- e) Site installation, commissioning and acceptance tests
- f) Insurance for transit, storage at site, erection, testing and commissioning
- g) Preparation and submission of operation and maintenance manual and training of O&M staff in optimum use of these manuals
- h) Set of spare parts for five years trouble free operation. A schedule of spare parts is required to be annexed.

#### 5.1.2 Auxiliaries and other item

- (i). Oil pressure unit – complete with oil tank, 2 nos. of OPU pump- motor-set, pressure accumulator complete with operating system, control and instruments
- (ii). Turbine Guide Bearing with coolers
- (iii). Governor, speed signal generator, over speed trip device
- (iv). All parts and accessories required to make a complete operating unit for controlling and regulating the speed of the turbine in conformity with performance characteristic
- (v). Oil for governor, lubricating oil and grease for flushing and first filling with 20% extra quantity.

## **5.2 Design Conditions**

### **5.2.1 Project arrangement**

It should contain detailed description of project with general arrangement drawings of power house and water ways at the high and low pressure side such as channels, galleries, penstocks, valves/gates, etc. The data should be clear so that Bidder may be aware of physical conditions that may affect detailed design.

### **5.2.2 Hydraulic conditions**

- a) Maximum water level u/s (m)
- b) Maximum tail water level (m)
- c) Minimum tail water level (m)
- d) Maximum gross head (static) in (m)
- e) Maximum net head (m)
- f) Rated head (Design) (m)
- g) Discharge (Q) Maximum (Cumec)
- h) Discharge (Q) Minimum (Cumec)
- i) Discharge (Q) Normal (Cumec)
- j) Range of water temperature (°C)
- k) Water quality analysis (chemical, corrosive nature biological, suspended solids)
- l) Range of ambient Temperatures and humidity (tropical environment or extreme cold need to be clearly mentioned)

### **5.2.3 Specified conditions**

- (a) Models of operation - Base load or peaking
  - Anticipated number of start – stop per year
  - Capacity factor of power plant
  - Special operating features e.g. synchronous condenser, spinning reserve, isolated, black starting, draining through turbine, etc.,
- (b) Rated output at rated discharge and rated head in kW
- (c) Speed in rpm
- (d) Direction of rotation - clockwise or anti clock wise viewing from generator end side

Besides above following considerations are also important.

### **5.2.4 Sand erosion considerations**

Risk of sand erosion may influence design and operation of hydro-turbine. Technical specification should indicate the content of suspended solids, their type, size and shapes. For this water samples should be drawn during rainy season periodically and petrographic analysis of silt contents must be got done.

### 5.2.5 Safety requirements

All parts of turbine shall be designed and constructed to safely withstand the maximum stresses during the normal running ,runaway, short circuit conditions or out of phase synchronization and brake application. The maximum unit stresses of the rotating parts shall not exceed  $2/3^{\text{rd}}$  of the yield point of the material. For other parts factor of safety based on yield point shall not be less than three in normal condition. For over load short circuit condition, a factor of safety of 1.5 (one & half) on yield' point shall be permitted.

### 5.3 Performance Guarantees and Liquidated Damages

Maximum output and efficiency of turbine at design head shall be stated in Guaranteed Technical Particular of turbine and will be guaranteed by equipment supplier. 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.

Field test (as per IEC-60041-1991) shall form the final basis to establish fulfillment of guarantees of the turbine and for the purpose of liquidated damage and rejection of plant.

#### 5.3.1 Weighted average efficiency

The weighting factors i.e.  $k_1, k_2, k_3, k_4$  etc for each load case should be proportional to energy production at that particular load. The weighted average efficiency formula with weighted factor is to be given here in the following form which is a typical example, the weighting factor “ k “ is to be taken as per actual discharges of the stream/ river of the actual project:

$$\eta_T (AV) = k_1 \eta_{T110} + k_2 \eta_{T100} + k_3 \eta_{T80} + k_4 \eta_{T60} + k_5 \eta_{T40}$$

where :  $k_1 + k_2 + k_3 + \dots + k_n = 1$

and : for example if a plan as per availability of discharge flow duration curved is able to run.

- a) at 110% load for 10% of total running hours for financial service life
- b) at 100% load for 50% of total running hours for financial service life
- c) at 80% load for 25% of total running hours for financial service life
- d) at 60% load for 10% of total running hours for financial service life
- e) at 40% load for 5% of total running hours for financial service life

then :  $k_1 = 0.1, k_2 = 0.5, k_3 = 0.25, k_4 = 0.1, k_5 = 0.05$

and :  $\eta_{T(AV)} = 0.1\eta_{T110} + 0.5 \eta_{T100} + 0.25 \eta_{T80} + 0.1\eta_{T60} + 0.05 \eta_{T40}$

$\eta_{T(AV)}$  = weighted average efficiency of turbine

$\eta_{T110}, \eta_{T100}, \eta_{T80}, \eta_{T60}, \eta_{T40}$  = Efficiency at 110%, 100%, 80%, 60% & 40% of rated output at designed head.

#### 5.3.2 Bid evaluation

For evaluation purposes, with each 0.1% decrease of the weighted average efficiency from a given base (highest rated average efficiency offered by any tenders) the tender price would be increased by the value of energy lost on account of less efficiency. The unit value of energy would have reasonable relationship to the energy loss and the subsequent revenue decrease over the assumed financial service life of the machine.

The basis for selection of the offer will be overall economy to the purchaser considering powerhouse civil works, values of efficiency, prices of matching generator and power house auxiliaries etc. The speed of the turbine and its design shall be such as to result in the most optimum generating unit at the least cost.

### **5.3.3 Output and efficiency tests**

Test as prescribed in IEC-60041-1991 shall be conducted at different heads and nozzle openings to determine guaranteed efficiency parameters. Any deviation from provisions of tests in IEC-60041-1991 should be clearly stated in the offer. Bidders shall furnish details of test methods, agency which will conduct the test, provisions to be made for field testing, calibration of instruments for purposes of test and all other relevant details. Contractor shall be under obligation to accept these tests for purchase of liquidated damages.

Purchaser reserves the right to appoint the contractor or any independent agency or agency recommended by the contractor for conducting these, cost of which will be borne by the contractor in any case.

### **5.3.4 Penalty for short fall in weighted average efficiency and output**

Penalty shall be applicable at the rate of ½ (half) percent of total unit price of turbine for each one tenth of one percent by which test figure is less than corresponding guaranteed figure. The penalty for short fall in output in kW shall be calculated separately and total penalty will be sum of two. However, total amount penalty shall not exceed mutually agreed percentage (say 10%) of the total unit price of turbine or with no upper limit.

### **5.3.5 Rejection limit**

The purchaser has the right to reject the turbine if the test value of either weighted average efficiency or rated output is less than the corresponding guaranteed value of 2 (two) percent or more after allowing agreed tolerance in computation of efficiency.

### **5.3.6 Cavitation guarantee**

The runner should be guaranteed against excessive pitting caused by cavitation for 18 months from the date of commissioning or 8000 hrs of operation whichever is earlier. Excessive pitting shall be defined as the removal of metal from the runner of weight '(w)' where

$$w = 0.15 D^2$$

where 'D' is PCD of runner buckets and 'w' is the weight in kg checking of this guarantee shall be as per IEC 61609-1991.

In case cavitation pitting is exceeding guaranteed value the turbine supplier will take corrective measures at his own cost. Turbine after modification etc. shall be subject to cavitation guarantee as per original equipment.

### **5.3.7 Vibration and noise level**

The turbine design shall ensure smooth and quiet operation with low vibrations, power fluctuation and noise.

The vibration amplitude at shaft shall not exceed the values specified in ISO-7919 (part-I) and ISO-3945 or VDI 2056 and VDI 2059 when measured with instrument 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 machine hall.

### **5.3.8 Runaway speed**

The maximum runaway speed shall be stated and guaranteed by the supplier. All rotating parts and bearings shall be capable of withstanding continuously the runaway speed attained with nozzles fully open and the generator disconnected and unexcited and with gross maximum head on turbine, without any damage to its parts for every such occurrence provided that the cooling arrangements are functional and for 30 minutes without cooling water.

### **5.3.9 Speed rise, pressure rise and inertia**

The moment of inertia of the generating unit and closing time of deflector should be so selected that maximum momentary speed rise of unit shall not exceed 40% of normal speed and pressure rise shall not exceed 25% of maximum head. The turbine manufacturer shall coordinate with the generator manufacture to achieve desired fly wheel affect.

### **5.3.1 Model test**

The design of turbine offered shall be based on a previous homologous model test carried out as per IEC test code publication no 60193&60193A and relevant Indian Standards. The tenderer should provide sufficient details of model test to the purchaser so as to ensure surety that such test has been carried out.

Model test results shall be subject to purchaser's approval. Manufacturing of prototype turbine should be commenced after approval of test results.

## **5.4 General Arrangement and Construction**

Construction and general arrangement of Pelton turbine can be subdivided in following:

- (i) Embedded parts
- (ii) Stationary / removable parts
- (iii) Rotating parts

### **5.4.1 Embedded parts**

#### **5.4.1.1 Manifold (Used for Vertical Shaft Pelton Turbine)**

Manifold is the piping or ducting which carries water from penstock to turbine inlet and runners. It should be so designed that head losses are minimum.

A brief description of manifold and its bifurcation (as per no. of nozzles) along with, number of jets, design pressure, test pressure, internal pressure during embedment, concrete embedment pour rate, type of material quoting relevant Indian Standard, protective coating, should be given in this para.

Besides above location, size and type of turbine inlet connection & all other connections e.g. brake jets, cooling water, access for inspection details of all indication & test connections & devices, erection support and handling devices should also be narrated.

#### **5.4.1.2 Turbine housing**

Brief description along with tolerances in location and plan, provisions for concrete placement and grouting, details of connections (e.g. turbine pit drain, test connections etc), erection support and handling devices etc. Type of material for its fabrication quoting relevant ISS.

#### **5.4.2 Stationary removable parts**

General description and specific requirements of stationary removable parts should be narrated in this section.

##### **5.4.2.1 Branch pipes (including intake and nozzle pipe)**

The term branch pipe is used for horizontal shaft Pelton turbines.

This para should include general description of branch pipe, type of material for fabrication quoting relevant Indian Standard, no. of jets, design pressure, test pressure, protective quoting, transportation and erection supports and handling devices.

Besides details of turbine inlet connections and other connection (e.g. Brake jet, cooling water etc.) with tolerances, description of all indications, test connections should also be given.

##### **5.4.2.2 Upper turbine housing (if not embedded)**

Brief description, design pressure, dismantling joint, material for fabrication quoting relevant Indian Standard, protective quoting, tolerance in plan & elevation, details of connection and erection support and handling devices should be given.

##### **5.4.2.3 Turbine cover**

Type of material for fabrication, its location on turbine housing or on pit floor. The cover should be strong but dismantlable as it is meant for service access to the runner. Special loading conditions, if any protective coating should be described here.

##### **5.4.2.4 Brake jet assembly**

Brief description, number of jets, control system etc. should be given here.

### **5.4.3 Technical specification for injector and deflector system**

Injector or deflector system are closely related to each other as such will be dealt together.

#### **5.4.3.1 Injector system**

Brief Description of injector (nozzle assembly) and servomotor having components viz. nozzle, needle, oil piping, liver link connections etc. should be given.

Besides above requirement of arrangement (e.g. number of jet, internal/ external servomotor etc.), full range of manifold/ branch pipe pressure, oil pressure, opening / closing rates, type of material for manufacturing.

#### **5.4.3.2 Deflector system**

Description of deflector system and component viz. deflector, deflector servomotor, oil piping, needle deflector link, needle deflector combining mechanism, full range of manifold/ branch pipe pressure, oil pressure, type of material for fabrication quoting relevant Indian Standard should be given in this para.

### **5.4.4 Technical specifications for rotating parts, guide bearing and seals**

Brief description of rotating parts should be narrated in this section:

#### **5.4.4.1 Runner**

Brief description along with type of material (13/4 Cr- Ni Stainless steel) for its manufacture quoting relevant Indian Standard. The material should be resistant to corrosion, sand erosion, cavitation pitting. Requirement of devices for erection and subsequent maintenance should be given. Proper shape and finish of buckets should be ensured to limit cavitation/ erosion damage. Quality control during manufacture of runner is very important to have good end product.

#### **5.4.4.2 Main shaft & coupling**

The turbine shaft shall be forged carbon steel or alloy steel conforming to IS or other equivalent international standards. Wherever the flanges are integral with the shaft, the same should conform to American standard ANSI-49.1, 1967. For long larger size shafts, tubular construction of proven design will also be considered. The turbine shaft shall be connected to the runner on one side and to the gear box/flywheel generator shaft on the other side. It shall be of ample size to transmit torque at rated speed without excessive vibration or any distortion.

A renewable and removable sleeve of stainless steel shall be provided wherever the shaft passes through a shaft seal or a gland.

The turbine manufacturer shall co-ordinate and co-operate with the generator manufacturer for proper design and construction. The final alignment of the shaft at site shall

be the responsibility of the generator manufacturer. Coupling guard shall be provided by the manufacturer.

#### **5.4.4.3 Turbine guide bearing**

The turbine bearings can be:

The pad type or sleeve type or Babbitt lined, oil/grease lubricated either self-lubrication or forced lubrication type.

Anti-friction ball, roller bearings, oil or grease lubricated. Water lubricated pad type. In this case the shaft shall have stainless steel removable sleeve lining where it passes through the bearing. The bearings shall be guaranteed for a minimum continuous operation of 100,000 (one hundred thousand) hours and the design and performance shall be well proven and established.

The turbine shall be provided with adequate number of bearings. The bearings shall be designed to withstand operation at maximum runaway conditions with cooling water supply on (if cooling water is provided) for a period of not less than 30 minutes and also for operation at runaway speed without cooling water supply for 15 minutes. The bearings shall be provided with a dial type or resistance type thermometer and a pressure gauge with provision for alarm annunciation/shut down on excessive bearing temperatures. The number and type of bearings shall be stated in the tender.

#### **5.4.4.4 Main shaft seal**

The shaft gland shall be of labyrinth type.

### **5.4.5 Technical specifications for miscellaneous components**

#### **5.4.5.1 Walkways, access platform and stairs**

These should include walkway and railing in turbine pit and its access runner inspection platform. Description of minimum requirement, loading requirements, applicable safety codes, should also be given.

#### **5.4.5.2 Lifting devices**

Requirement of lifting devices for runner and shaft, nozzle and deflector, regulating mechanism, turbine cover, servomotors, guide bearing & coupling bolts etc. should be narrated.

#### **5.4.5.3 Special tools & tackles**

Requirement of special tools & tackles for loosening and tightening of coupling bolts, dismantling and assembly of nozzle and deflector assembly, special wrenches, jacks, shaft lifting device, slings etc should be mentioned in this clause.

#### **5.4.5.4 Standard tools**

Complete new set of standard tools for maintenance of turbine should be given.

#### **5.4.5.5 Turbine pit hoist**

This is required for maintenance of guide bearing, deflector levers etc.

#### **5.4.5.6 Name plate**

Minimum data to be given on name plate, its size and location should be given.

#### **5.4.6 Technical specification of auxiliaries**

Brief description of bearing lubrication system, top cover drainage system, pressure relief valves, air admission system, oil pressure unit, control, indication and annunciation should be given in this section.

#### **5.4.7 Technical specification for instrumentation, control and safety devices**

Brief description of instrumentation, control and safety devices preferred should be narrated e.g. unit start inter locks, low flow bearing cooling, indication for bearing oil level, bearing temperatures and protection requirement viz., bearing temperature high.

Thus each turbine shall be provided with complete set of instruments, gauge, control and protection devices at appropriate place to monitor the condition of unit during normal running and emergencies.

#### **5.5 Spare Parts**

List of spare parts required for five years trouble free operation of the plant should be given and these should be manufactured with the main plant and delivered with turbine components. Minimum requirement of spares should include, bearing shell or set of pads, set of nozzles & deflectors, shaft seal wear components, complete set of seals, o-rings gaskets for dismantling and reassembly, set of studs, nuts, bolts used for different assembly.

Tenderers should be requested to submit their list of recommended spares and unit price with the tender.

#### **5.6 Shop Assembly and Test**

Bidder should be asked to submit quality assurance plan indicating test to be performed and witnessed by the purchaser and their acceptance criteria. This quality plan should be approved by the purchaser after due diligence. Quality assurance plan should essentially include the following:

- a) All assemblies and subassemblies marked and dowelled to ensure quick assembly at site
- b) Static and dynamic balancing of runner
- c) Non destructive test of welded joints

- d) Performance test for individual auxiliary equipment
- e) All motors pumps, compressors to be tested as per relevant Indian Standards
- f) Routine test reports of all bought out items shall be finished before dispatch for approval
- g) Injector and deflector operating mechanism shall be assembled in the shop and hydraulic pressure test should be performed to establish proper opening and closing at designed oil pressure and also oil leakages in the system.
- h) Hydraulic testing of servomotors, stroke checking, oil leakage checking
- i) Material test of important components such as buckets, turbine shaft, guide pads, bushes, piston rods and other components shall be carried out as per agreed plan

## **5.7 Site Installation Testing and Commissioning**

The bidder should be asked to prepare erection procedure and check points at every stage so as to set elevation and centerline as also form of different components of turbine to be installed at site. The procedure should contain full cross referencing to turbine drawing and to location of measurement points and should become a part of maintenance manual erection tolerances should follows Indian and International practices or standards.

The procedure should give limit for location of embedded parts which need to be verified and monitored before pouring of concrete.

The procedure should also specify measurement records to be made during installation and setting of components for example relative location, clearances, elevation, rotational checks etc. It should cover requirements of connected generators.

### **5.7.2 Field acceptance test**

The field acceptance tests shall be carried out as per relevant Indian or International Standard for Pelton turbine. The arrangements for these testing including testing instruments, device shall be within the scope of contractor's work.

#### **(a) Tests during erection**

- (i) 100% radiographic testing of all welded seams of inlet pipe, manifold branch pipe and other welded components of machine.
- (ii) Pressure testing of manifold/ branch pipe
- (i) Measurement of clearances between guide pads & bearing journals of all guide bearings.
- (ii) Checking alignment of generator and turbine shaft and setting of bearings.
- (iii) Checking of splitter ridge and notch radius tolerance during rotation of runner. The axial tolerance on splitter ridge and radial tolerance on bottom of notch in no case should exceed  $\pm 0.3\%$  of PCD.

#### **(b) Commissioning Tests**

Once erection is complete to the satisfaction of purchaser following tests shall be carried out

- (i) Check dynamic balancing of machine
- (ii) Operation of unit at no load – check run out of rotating parts, behavior of various bearings, setting over speed trip device
- (iii) Operation of unit at agreed, part loads and full load – check run out of rotating parts, behavior of various bearings, check vibration pulsation and noise and ensure these are within limits.
- (iv) Load rejection test at various agreed part loads & full load – check speed rise, pressure rise and ascertain these are within limit.
- (v) Check proper operation of all turbine auxiliaries.
- (vi) Perform all tests for meeting performance guarantees.

### 5.7.3 Inspection for cavitation pitting

It is to be ensured that operating records during guarantee period are properly maintained. It is also to be verified that machines are operated within specified range of output head and discharge.

After specified period of running of machine joint inspection is to be carried for cavitation pitting and establishing that cavitation is within limits and provisions of cavitation guarantee are met.

## 5.8 Technical Specification of Cross Flow Turbine & Auxiliary Equipment

### 5.8.1 Scope

The specification covers the design, engineering, manufacture, supply, installation, testing and commissioning of a complete hydro-power generating powerhouse comprising of desired no. of units having turbine units suitably coupled to Synchronous generator. The system shall also include Electronic Load Controller for each turbine for load governing and regulation of turbine speed/generated frequency and electrical power distribution panel with necessary protection against over-current, earth fault, under-voltage and over-voltage. Provision for synchronizing of generated output to Grid/Second Turbine-generator output must be available in the panel with necessary protection.

It is preferred that a common base frame for turbine and generator be provided for ease of alignment of generator with the turbine for drive pulley alignment, as may be required. Following details are to be given:

Type		Horizontal Cross flow Turbine
Unit Capacity	---	KW
Number of Units	---	No.
Rated Head	---	M
Rated Discharge	---	Cumec.
Diameter of Runner	---	mm
Runner Width	---	mm
No. of Runner Blades	---	No.
Turbine Speed	---	RPM
Regulation	---	Radial Plate moved by Worm wheel (for example)
Type of Bearing	---	Spherical-roller (for example)
Make	---	SKF/ FAG (for example)

## **5.8.2 Type and Rating**

### **5.8.2.1 Turbine**

The turbines offered shall be cross-flow type. A penstock adaptor must be provided at the inlet suitable for connecting the penstock pipe of appropriate size at the turbine inlet.

The penstock adaptor must be provided with matching flanges with necessary fasteners for fixing of the penstock pipe.

The turbine should be capable of generating power so that specified kW of power can be measured at the generator terminals.

The turbine should be capable of operating between 110% to 40% variation of rated discharge and capable of synchronization with other machines and with the grid.

The turbine shall be so constructed as to allow all the removable parts to be dismantled conveniently. All the components shall be neatly arranged and shall be easily accessible for O and M.

### **5.8.2.2 Runaway speed**

All parts and bearing should be capable of withstanding continuous runaway speed attained under any combination of head and load conditions with inlet valve fully opened, generator disconnected and unexcited. The occurrence of runaway condition should not damage the turbine parts.

### **5.8.2.3 Noise level**

Maximum noise level resulting from any of the operating condition shall not exceed 85 dB (A) at any place 1.0 m away from operating equipment in the machine hall.

### **5.8.2.4 General arrangement and construction runner**

The runner shall be of stainless steel with approximate content 13% chromium and 4% nickel. It should be either casted or fabricated. The runner would have adequate number of smooth blades. It should be dynamically balanced in the works.

### **5.8.2.5 Shaft and coupling**

The turbine shaft should be forged carbon steel or stainless steel or alloy conforming to Indian standard or equivalent International standard.

The turbine supplier shall collaborate with the generator supplier for the coupling arrangement. The flexible rubber coupling shall be preferred.

### **5.8.2.6 Casing**

The casing shall fabricate from welded steel plate/mild plates and shall have suitable sections for ease of transport and its limitations.

### **5.8.2.7 The turbine bearings**

The turbine bearings should be Anti-friction ball, roller bearing, oil or grease lubricated sleeve type.

These bearings shall be guaranteed for a minimum continuous operation of 100000 (one lack) hours and the design and performance shall be proven and established.

### **5.8.2.8 Shaft gland**

The gland shall effectively prevent leakage of water along the shaft under all operating conditions and at stand still prevent entry of air. Arrangement of cooling water supply of shaft gland will also be in the scope of bidder.

### **5.8.2.9 Draft tube (If applicable)**

The draft tube can be either straight or elbow shaped. The design of draft tube shall be such as to ensure the best overall efficiency for the turbine, stable and pulsation free operation of the machines.

### **5.8.2.10 Shop assembly and tests**

The following assemblies and tests shall be carried out on the turbine and associated equipment at the manufacturer's works before dispatch in the presence of representative of the owner, if desired by the Owner, and test certificate shall be submitted.

- i. The turbine manufactured first, shall be assembled in the shop to the extent possible.
- ii. Dynamic balancing of runner.
- iii. Hydrostatic testing at 1.5 times the maximum static/working pressure including water hammer for not less than 30 minutes for the spiral case, servomotors, etc.
- iv. Non-destructive testing of welds.
- v. Performance tests for individual auxiliary equipment.
- vi. Complete assembly and simulation test of governors / load controller.
- vii. Assembly of spiral case and draft tube liner.
- viii. All motors/pumps/compressors etc. shall be tested as per relevant Indian or other standards.
- ix. Routine test reports of all the bought out items shall be furnished before approval for dispatch.

## **5.9 Pressure Gauge**

Two pressure gauge shall be provided in the P.H. to read the pressure of water just before it enters the turbine. It shall have scale to read approximately half-scale at gross head and shall be mounted at 45° with vertical.

### 5.9.1 Manifold

The manifold to carry water from penstock to the turbine inlet and runner shall be designed so as not to introduce large additional head losses. This can be verified by following thumb-rules:

- (i) Do not allow the velocity of water in the penstock to increase as it passes through the penstock.
- (ii) Velocities in the manifold should not exceed :
  - a) 3 m/s in straight pipes
  - b) 2.5 m/s in bends up to 45°.
  - c) 2.0 m/s in bends up to 90°.

### 5.9.2 Inlet Valve

- i. An inlet valve (a valve at the foot of penstock) shall be provided unless:
  - a) It is possible to quickly, safely and in a routine manner divert water away from the turbine or the mouth of the penstock in order to shut down the turbine (e.g. on some low head sites it may be possible to divert water at the mouth of the penstock)
  - b) If the guide vane of a Cross Flow closes off the flow sufficiently.

#### ii. Location

The inlet valve shall be located in the P.H. and be easily accessible. It shall be rated at maximum penstock pressure.

#### iii. Operational Speed

The valve must be slow closing type or should have an apparatus which shall prohibit fast closing e.g.:

- a) Fitting of a much smaller second valve in parallel to the manifold valve, which shall be pad-locked in the open position and kept open when the main valve is closed.
- b) A gearing mechanism to ensure very slow closing operation.

### 5.9.3 Safety Guards

All moving parts shall be shielded by a strong and durable wire mesh. The size of the mesh shall be small enough to prevent the entry of hands and arms of the children. The guards shall be electrically earthed and kept permanently secured by locks.

### 5.9.4 Minimum Weighted Average Efficiency ( $\eta_{av}$ )

- i. The weighted average efficiency of the turbine – generator unit, calculated by the following expression should not be less than 60%

$$\eta_{av} = 0.5 \{ \eta_{t 100} \times \eta_{g 100} + \eta_{t 50} \times \eta_{g 50} \},$$

where

$\eta_{t 100}$ ,  $\eta_{g 100}$ ,  $\eta_{t 50}$ ,  $\eta_{g 50}$  are efficiencies of turbine and generator at 100% and 50% rated outputs, respectively at rated head.

- ii. (a) For efficiency of turbine, the performance curves of similar offered turbine manufactured by the manufacturer of which turbine are being quoted by the bidder. (tested by independent institution), be provided, or the value obtained as per the field tests on the turbine carried out as specified in IEC or equivalent international or national code shall be taken.
- (b) For efficiencies of generator the value obtained as per field tests as specified in above codes shall be taken.

#### Bid Evaluation Equalization for Short Fall in $\eta_{av}$

For each 1 (one) % or part thereof by which  $\eta_{av}$  (Sub – clause 2.2.1) is lower than the highest offered  $\eta_{av}$  in any of the bids received, 3 (three) % of total price of turbine – generator unit offered in the bid under evaluation shall be added to the offered price of each turbine-generator unit.

### 5.9.5 Cavitation Guarantee

The bidder shall guarantee the runner against excessive pitting/cavitation for Eighteen (18) months for the date of commissioning or 8000 (Eight thousand) hours of operation, which is earlier.

### 5.9.6 Guaranteed Performance

Flow variation Capability	---to---	%
(i). Design efficiency at rated flow	---	%
(ii). Efficiency at 50% flow	---	%
(iii). Output at rated flow	---	kW
(iv). Output at 50% flow	---	kW

### 5.9.6 Recommended Test

- (i). Output Test
- (ii). Efficiency Test
- (iii). Over Speed Test
- (iv). Run Away Speed Test
- (v). Noise Level Check
- (vi). Vibration check

## 6.0 TECHNICAL SPECIFICATIONS FOR TUBLAR / BULB TURBINE, AND SPEED INCREASER

### 6.1 General

Tubular turbine is an axial flow turbine which can have following variations and can be placed horizontally for power plants up to 25 MW capacity (SHP) :

- (i) Adjustable runner blades / adjustable wicket gates - Kaplan
- (ii) Adjustable runner blades / fixed wicket Gates – Semi Kaplan
- (iii) Fixed runner blades / adjustable wicket gates – Propeller
- (iv) Fixed runner blades/ fixed wicket gates – Propeller with fixed wicket gates

The first variation depicts the most efficient axial flow turbine under varying head, flow and load conditions as such this has been selected for preparing these guide lines. Tubular turbine can have any of the above arrangement of runner and wicket gates. These guide lines can be easily modified for any of the above variation.

Further in a horizontal unit generator can be housed inside the bulb placed in water passage or in the pit which is typically open for full width and length vertically to the upper level of powerhouse (pit unit). Most pit units have speed increaser to reduce the size of generator and enclosing pit. For preparing these guide lines bulb type arrangement of generator have been selected.

## 6.2 Scope for Tublar / Bulb Turbine

The scope of work under this section should include design, material selection, manufacture, shop assembly and testing, transportation and delivery to site, insurance, storage at site, installation, commissioning, field acceptance tests, warrantee and other services as specified or required.

## 6.3 Detailed list of major items should be as follows:

### 6.3.1 Turbine

- a – Type of Turbine - Complete with all embedded, removable static and rotating parts
- b – No. of units - ----- Nos.
- (c)– Shaft - Horizontal or Vertical
- d – Rated Power at rated Head and rated discharge - kW
- b  
ine Model Testing
- (ii). Tools, slings and handling devices for assembly and maintenance of turbine
- (iii). Transportation and delivery at site
- (iv). Site installation, commissioning and acceptance tests.
- (v). Insurance for transit, storage at site, erection testing and commissioning
- (vi). Preparation and submission of operation and maintenance manual and training of O&M staff in optimum use of these manuals
- (vii). Set of spare parts for five years of trouble free operation. A schedule of spare parts should be annexed.

### 6.3.2 Auxiliaries and other item

- (i) Turbine pit drainage system
- (ii) Tail water air admission system
- (iii) Oil pressure unit – complete with oil tank, 2 nos. of OPU pump- motor-set, pressure accumulator complete with operating system, control and instruments

- (iv) Turbine Guide Bearing with coolers
- (v) Shaft gland seal
- (vi) Governor, speed signal generator, over speed trip device
- (vii) All parts and accessories required to make a complete operating unit for controlling and regulating the speed of the turbine in conformity with performance characteristic
- (viii) Oil for governor, lubricating oil and grease for flushing and first filling with 20% extra quantity.

## 6.4 Design Conditions

### 6.4.1 Project arrangement

It should contain detailed description of project with general arrangement drawings of power house and water ways at the high and low pressure side such as channels, galleries, penstocks, surge tank, valves/gates, etc. The data should be clear so that Bidder may be aware of physical conditions that may affect detailed design.

### 6.4.2 Hydraulic conditions

- a) Maximum water level u/s (m)
- b) Maximum tail water level (m)
- c) Minimum tail water level (m)
- d) Maximum gross head (static) in (m)
- e) Maximum net head (m)
- f) Rated head (Design) (m)
- g) Discharge (Q) Maximum (Cumec)
- h) Discharge (Q) Minimum (Cumec)
- i) Discharge (Q) Normal (Cumec)
- j) Range of water temperature (°C)
- k) Water quality analysis (chemical, corrosive nature biological, suspended solids)
- l) Range of ambient Temperatures and humidity (tropical environment or extreme cold need to be clearly mentioned)

### 6.4.3 Specified conditions

- Modes of operation:
  - Base load or peaking
  - Anticipated numbers of start-stop per year
  - capacity factor of power plant
  - special operating features e.g. synchronous condenser, spinning reserve, isolated, black starting draining through turbine, etc.
- Rated output at rated discharge and rated head
  - - - - - KW
- Speed
- Direction of rotation
  - r.p.m.
  - clockwise or anticlockwise while viewing from generator.

#### 6.4.4 Besides above following considerations are also important

##### (i) Sand erosion considerations

Risk of sand erosion may influence design and operation of hydro turbine. Technical specification should indicate the content of suspended solids, their type, size and shapes. For this water samples should be drawn during rainy season periodically and petrographic analysis of silt contents must be got done.

##### (ii) Safety requirements

All parts of turbine shall be designed and constructed to safely withstand the maximum stresses during the normal running runaway, short circuit conditions or out of phase synchronization and brake application. The maximum unit stresses of the rotating parts shall not exceed  $2/3^{\text{rd}}$  of the yield point of the material. For other parts factor of safety based on yield point shall not be less than three in normal condition. For over load short circuit condition, a factor of safety of 1.5 (one & half) on yield' point shall be permitted.

#### 6.5 Performance Guarantees and Liquidated Damages

Maximum output and efficiency of turbine at design head shall be stated in Guaranteed Technical Particular of turbine and will be guaranteed by equipment supplier. 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.

Field test (as per IEC-60041-1991) shall form the final basis to establish fulfillment of guarantees of the turbine and for the purpose of liquidated damage and rejection of plant.

##### 6.5.2 Weighted average efficiency

The weighting factors i.e.  $k_1, k_2, k_3, k_4$  etc for each load case should be proportional to energy production at that particular load. The weighted average efficiency formula with weighted factor is to be given here in the following form which is a typical example, the weighting factor “ $k$ ” is to be taken as per actual discharges of the stream/ river of the actual project:

$$\eta_T (AV) = k_1 \eta_{T110} + k_2 \eta_{T100} + k_3 \eta_{T80} + k_4 \eta_{T60} + k_5 \eta_{T40}$$

where :  $k_1 + k_2 + k_3 + \dots + k_n = 1$

and : for example if a plan as per availability of discharge flow duration curved is able to run.

- at 110% load for 10% of total running hours for financial service life
- at 100% load for 50% of total running hours for financial service life
- at 80% load for 25% of total running hours for financial service life
- at 60% load for 10% of total running hours for financial service life
- at 40% load for 5% of total running hours for financial service life

then :  $k_1 = 0.1, k_2 = 0.5, k_3 = 0.25, k_4 = 0.1, k_5 = 0.05$

and :  $\eta_{T(AV)} = 0.1 \eta_{T110} + 0.5 \eta_{T100} + 0.25 \eta_{T80} + 0.1 \eta_{T60} + 0.05 \eta_{T40}$

$\eta_{T(AV)}$  = weighted average efficiency of turbine  
 $\eta_{T100}$ ,  $\eta_{T80}$ ,  $\eta_{T60}$ ,  $\eta_{T40}$  = Efficiency at 110%, 100%, 80%, 60%, & 40% of rated output at designed head.

### **6.5.3 Bid evaluation**

For evaluation purposes, with each 0.1% decrease of the weighted average efficiency from a given base (highest rated average efficiency offered by any tenders) the tender price would be increased by the value of energy lost on account of less efficiency. The unit value of energy would have reasonable relationship to the energy loss and the subsequent revenue decrease over the assumed financial service life of the machine.

The basis for selection of the offer will be overall economy to the purchaser considering powerhouse civil works, values of efficiency, prices of matching generator and power house auxiliaries etc. The speed and setting of the turbine and its design shall be such as to result in the most optimum generating unit at the least cost.

### **6.5.4 Output and efficiency tests**

Test as prescribed in IEC-60041-1991 shall be conducted at different heads and guide vane openings to determine guaranteed efficiency parameters. Any deviation from provisions of tests in IEC-60041-1991 should be clearly stated in the offer. Bidders shall furnish details of test methods, agency which will conduct the test, provisions to be made for field testing, calibration of instruments for purposes of test and all other relevant details. Contractor shall be under obligation to accept these tests for purchase of liquidated damages.

Purchaser reserves the right to appoint the contractor or any independent agency or agency recommended by the contractor for conducting these, cost which will be borne by the contractor in any case.

### **6.5.5 Penalty for short fall in weighted average efficiency and output**

Penalty shall be applicable at the rate of ½ (half) percent of total unit price of turbine for each one tenth of one percent by which test figure is less than corresponding guaranteed figure. The penalty for short fall in output in kW shall be calculated separately and total penalty will be sum of two. However, total amount penalty shall not exceed mutually agreed percentage (say 10%) of the total unit price of turbine or with no upper limit.

### **6.5.6 Rejection limit**

The purchaser has the right to reject the turbine if the test value of either weighted average efficiency or rated output is less than the corresponding guaranteed value of 2 (two) percent or more after allowing agreed tolerance in computation of efficiency.

### **6.5.7 Cavitation guarantee**

The runner should be guaranteed against excessive pitting caused by cavitation for 18 months from the date of commissioning or 8000 hrs of operation whichever is earlier. Excessive pitting shall be defined as the removal of metal from the runner of weight '(w)' where

$$w = 0.15 D^2$$

where 'D' is the discharge diameter of runner and 'w' is the weight in kg checking of this guarantee shall be as per IEC 61609-1991.

In case cavitation pitting is exceeding guaranteed value the turbine supplier will take corrective measures at his own cost. Turbine after modification etc. shall be subject to cavitation guarantee as per original equipment.

#### **6.5.8 Critical & plant sigma**

Values of critical sigma as determined from cavitation model tests as per IEC 60193-1999,60193A-1999 shall be given in the form of curves for different heads of operation. Plant sigma curves as recommended by manufacturer shall also be plotted on it clearly to show the safety margin available.

#### **6.5.9 Vibration and noise level**

The turbine design shall ensure smooth and quiet operation with low vibrations, pressure pulsation, power fluctuation and noise.

The vibration amplitude at shaft shall not exceed the values specified in ISO-7919 (part-I) and ISO-3945 or VDI 2056 and VDI 2059 when measured with instrument 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 machine hall.

#### **6.5.10 Runaway speed**

The maximum runaway speed shall be stated and guaranteed by the supplier. All rotating parts and bearings shall be capable of with standing continuously the runaway speed attained with guide vanes fully open and the generator disconnected and unexcited and with gross maximum head on turbine, without any damage to its parts for every such occurrence provided that the cooling arrangements are functional and for 30 minutes without cooling water.

#### **6.5.11 Speed rise, pressure rise and inertia**

The moment of inertia of the generating unit and closing time of guide vanes should be so selected that maximum momentary speed rise of unit shall not exceed 45% of normal speed and pressure rise shall not exceed 25-35% of maximum head. The turbine manufacturer shall coordinate with the generator manufacture to achieve desired fly wheel affect.

#### **6.5.12 Model test**

The design of turbine offered shall be based on a previous homologous model test carried out as per IEC test code publication no 60193&60193A and relevant Indian Standards. The tenderer should provide sufficient details of model test to the purchaser so as to ensure surety that such test has been carried out.

Model test results shall be subject to purchaser's approval. Manufacturing of prototype turbine should be commenced after approval of test results.

## **6.6 General Arrangement and Construction Features**

The bulb turbine – generator unit shall be an axial flow, horizontal shaft, directly coupled immersed unit with two bearings located on the shaft. The turbine under consideration shall be Kaplan type. The generator will be located in water tight bulb located in water passage. The turbine will have following components:

### **6.6.1 Embedded components**

#### **6.6.1.1 Bulb structure and hatch cover**

General description of bulb structure and hatch or pit cover along with design pressure concrete embedment pour rate, type of material for its fabrication quoting relevant Indian Standard, location, size and type of other connections (cooling water, service air etc.) and maintenance access should be given.

#### **6.6.1.2 Stay ring**

Brief description, type material for its fabrication quoting relevant ISS, loads to be supported, tolerances in plan and elevation, erection supports and handling devices, should be given here.

#### **6.6.1.3 Discharge ring / runner chamber**

Brief description, type of material for its fabrication quoting relevant ISS, loading conditions, external pressures, minimum thickness, external rib arrangement, provision for removal of runner location & size of maintenance access and other connections tolerance in plan and elevation, erection supports handling devices should be narrated in this para.

#### **6.6.1.4 Draft tube and draft tube liner**

Brief description of draft tube along with, maximum design pressure for liner maximum allowable pressure pulsation amplitude, type material for manufacturing, maximum thickness of liner plate transportation and handing, dimensional tolerances, location and other details of downstream limit, details of inspection windows and devices should be narrated here.

Besides above location, size and details of connections (e.g. draft tube aeration piping, draft tube water levels controls indication and test device etc.) should also be given.

Details of permanent and temporary erection support, handling devices (anchors, tie rods, supports etc) should be narrated in this clause.

### **6.6.2 Stationary and removable components**

#### **6.6.2.1 Inner and outer ring**

Brief description, type of material for fabrication quoting relevant ISS should be given.

### **6.6.2.2 Guide vane bushings**

Brief description, type of material for fabrication quoting relevant ISS, special feature like self lubricated or grease lubricated etc. should be given.

### **6.6.2.3 Guide vanes (wicket gates)**

Brief description of guide vanes, rates for opening and closing, material type (corrosion, erosion resistant), hydraulic torque characteristic should be given.

For guide vane stem, type of material and any other requirement should be written.

### **6.6.2.4 Technical specification for guide vane regulating apparatus**

Brief description of guide vane regulating system should be narrated in this para.

#### **6.6.2.4.1 Servomotor**

Preferred location in turbine pit, type of material for manufacturing, maximum and minimum allowable operating pressure (if governor supplied separately), test pressure, opening and closing time, arrangement of seals, other requirements if any, for ease of operation and maintenance should be narrated in this para.

#### **6.6.2.4.2 Connecting rods**

Type of material, preferred arrangement and minimum bushing requirement should be mentioned.

#### **6.6.2.4.3 Regulating ring**

Brief description of arrangement of regulating ring, type of material for manufacturing, support requirement on head cover should be given here.

#### **6.5.6.2.4.4 Guide vane linkage**

Brief description of arrangement of GV linkage, type of material and individual adjustment on each guide vane in closed position to be narrated.

#### **6.6.2.4.5 Guide vane overload protection**

Description in brief arrangement of GV overload annunciation.

#### **6.6.2.4.6 Locking Devices**

Describe in brief preferred arrangement automatic or manual, “closed” or “open”, lock position detection, lock position annunciation.

### **6.6.2.5 Technical Specification of Rotating Parts, Guide Bearings and Seals**

#### **6.6.2.5.1 Runner**

- (i) Brief description of runner along with type material for runner components manufacturing quoting relevant standard (resistant to corrosion, erosion and

- cavitation) support of runner and shaft during erection and subsequent maintenance, requirement of static balancing should be given in this par
- (ii) Runner blades  
Runner water passage shape and finish of runner blades is important factor in reducing cavitation damages as such during manufacturing proper quality should be ensured.
  - (iii) Runner hub, cone, blade seals and bearings  
Brief description of runner hub, cone, blade seals and bearings type of material for their manufacturing quoting relevant Indian Standard.

#### **6.6.2.5.2 Runner blade regulating mechanism**

- (i) Blade servomotor  
General description, location (shaft, hub), material for manufacturing pressure testing, maximum and minimum allowable operating pressure, other requirement regarding O&M should be narrated.
- (ii) Runner blade trunion  
Brief description and material for manufacturing.
- (iii) Blade lever & links  
Brief description, type of material to be used for manufacturing, minimum bushing requirement should be given.
- (iv) Oil head  
Brief description, material type, piping connections, minimum bushing requirement
- (v) Rotating seal rings

Brief description covering type material which should be compatible to the material used on stationary wearing rings as also design i.e. removable or one piece with runner should be given in this paragraph.

#### **6.6.2.5.3 Main shaft & coupling**

The turbine shaft shall be forged carbon steel or alloy steel conforming to IS or other equivalent international standards. Wherever the flanges are integral with the shaft, the same should conform to American standard ANSI-49.1, 1967. For Kaplan turbines tubular construction shaft will be provided. The turbine shaft shall be connected to the runner on one side and to generator shaft on the other side. It shall be of ample size to transmit torque at rated speed without excessive vibration or any distortion.

A renewable and removable sleeve of stainless steel shall be provided wherever the shaft passes through a shaft seal or a gland.

The turbine manufacturer shall co-ordinate and co-operate with the generator manufacturer for proper design and construction. The final alignment of the shaft at site shall be the responsibility of the generator manufacturer.

#### **6.6.2.5.4 Turbine guide bearing**

The turbine bearings can be:

Babbit lined sleeve type or Babbitt lined, oil/grease self-lubrication type.

Anti-friction ball, roller bearings, oil or grease lubricated.

The bearings shall be guaranteed for a minimum continuous operation of 100,000 (one hundred thousand) hours and the design and performance shall be well proven and established.

The turbine shall be provided with adequate number of bearings. The bearings shall be designed to withstand operation at maximum runaway conditions for a period of not less than 30 minutes. The bearings shall be provided with a dial type or resistance type thermometer and a pressure gauge with provision for alarm annunciation/shut down on excessive bearing temperatures. The number and type of bearings shall be stated in the tender.

#### **6.6.2.5.5 Main shaft seal**

The shaft gland shall be of the stuffing box/carbon ring type with self-lubricated packing and lantern ring. Any other suitable type of shaft gland will also be considered. The gland shall effectively prevent leakage of water along the shaft under all operating conditions and at standstill and prevent entry of air. In case the location of the gland is below maximum tail water level, an inflatable rubber seal shall be provided for attending the main gland without dewatering the draft tube. A stainless steel sleeve shall be provided on the shaft where it passes through the gland.

- (i) Description of shaft, material type conforming to relevant Indian Standard, be designed to operate safely in combination with the generator rotor at any speed up to maximum runaway speed without detrimental vibration or objectionable distortion, type of coupling e.g. friction type with prestressed bolts, coupling bolt holes to meet interchangeability requirement, need of concentric hole through shaft for installing servo tube which feed pressurised oil to runner servomotors to be narrated in this para. Besides above define coordination with generator supplier for dimensional interface, critical speed and alignment.
- (ii) Coupling bolts, nuts and nut guards  
Specify material for manufacturing, interchangeability, locking device, details of nut guards at turbine and generator end.

#### **6.6.2.6 Technical specifications for miscellaneous components**

##### **6.6.2.6.1 Walkways, access platform and stairs**

It should include, walkway and railing in turbine pit and its access runner inspection platform. Description of minimum requirement, loading requirements, applicable safety codes, should also be given.

##### **6.6.2.6.2 Lifting devices**

Requirement of lifting devices for runner and shaft, guide vanes, regulating mechanism, inner / outer head cover, servomotors, guide vane operating mechanism in pit, bottom cover, guide bearing & coupling bolts etc. should be narrated.

#### **6.6.2.6.3 Special tools & tackles**

Requirement of special tools & tackles for loosening and tightening of coupling bolts, dismantling and assembly of overload protection device, guide vane levers, special wrenches, jacks, shaft lifting device, slings etc. should be mentioned in this clause.

#### **6.6.2.6.4 Standard tools**

Complete new set of standard tools for maintenance of turbine should be given.

#### **6.6.2.6.5 Name plate**

Minimum data to be given on name plate, its size and location should be given.

#### **6.6.2.7 Technical specification of auxiliaries**

Brief description of bearing lubrication system, guide vanes lubrication system, top cover drainage system, pressure relief valves, air admission system, lubrication of regulating mechanism control indication and annunciation should be given in this section.

#### **6.6.2.8 Technical specification for instrumentation control and safety devices**

Brief description of instrumentation, control and safety devices preferred should be narrated e.g. unit start inter locks, low flow bearing cooling, low flow shaft sealing lubrication etc., indication for bearing oil level, , bearing temperatures and protection requirement viz., bearing temperature high,

Thus each turbine shall be provided with complete set of instruments, gauge, control and protection devices at appropriate place to monitor the condition of unit during normal running and emergencies.

### **6.7 Spare Parts**

List of spare parts required for five years trouble free operation of the plant should be given and these should be manufactured with the main plant and delivered with turbine components. Minimum requirement of spares should include, bearing shell or set of pads, set of guide vane bushings, shaft seal wear components complete set of seals, o-rings gaskets for dismantling and reassembly set of head cover studs, other studs, nuts, bolts etc.

Tenderers should be requested to submit their list of recommended spares and price with the tender.

### **6.8 Shop Assembly and Test**

Bidder should be asked to submit quality assurance plan indicating test to be performed and witnessed by the purchaser and their acceptance criteria. This quality plan should be approved by the purchaser after due diligence. Quality assurance plan should essentially include the following:

- (i). All assemblies and subassemblies marked and dowelled to ensure quick assembly at site
- (ii). Static balancing of runner
- (iii). Non destructive test of welded joints
- (iv). Performance test for individual auxiliary equipment
- (v). All motors pumps, compressors to be tested as per relevant Indian Standards
- (vi). Routine test reports of all bought out items shall be finished before dispatch for approve
- (vii). Guide vanes and guide operating mechanism shall be assembled in shop to ensure proper clearance between end faces of guide vanes, clearance between consecutive guide vanes in fully closed position at three places, opening between consecutive guide vanes at 50%, 75% and 100% open position at three places, minimum force to move regulating ring with guide vanes freely
- (viii). Runner, runner blade operating system should be assembled in shop and hydraulic pressure test should be performed to ensure proper sealing of runner blades and their proper opening and closed at required oil pressure is established
- (ix). Hydraulic testing of servomotors, stroke checking, oil leakage checking
- (x). Material test of important components such as runner blades, guide vanes, turbine shaft, guide pads, bushes, piston rods and other components shall be carried out as per agreed plan
- (xi). Hydraulic testing of assembled Kaplan runner

## **6.9 Site Installation Testing and Commissioning**

The bidder should be asked to prepare erection procedure and check points at every stage so as to set elevation and centerline as also form of different components of turbine to be installed at site. The procedure should contain full cross referencing to turbine drawing and to location of measurement points and should become a part of maintenance manual erection tolerances should follows Indian and International practices or standards.

The procedure should give limit for location of embedded parts which need to be verified and monitored before pouring of concrete.

The procedure should also specify measurement records to be made during installation and setting of components for example relative location, clearances, elevation, rotational checks etc. It should cover requirements of connected generators.

### **6.9.1 Field acceptance test**

The field acceptance tests shall be carried out as per IEC 60041-1991 for field acceptance tests of hydraulic turbines. The arrangements for these test including testing device shall be within scope of the contractor's work.

Test during erection:

- (i). 25% radiographic testing of all site welded seams of underwater parts
- (ii). Measurements of clearances of runner & runner chamber
- (iii). Measurement of guide vane gaps
- (iv). Hydraulic pressure testing of Kaplan turbine runner

## 6.9.2 Commissioning tests

Once erection is complete following tests are required to be carried out

- (i) Relation between servomotor stroke and guide vane opening
- (ii) Determination of GV opening and blade opening at no load
- (iii) Rotational checks for establishing alignment of shaft
- (iv) (a) GV opening / closing time by dry stroking  
(b) Runner blade opening and closing time by dry stroking
- (v) Relation between guide vane opening and runner blade opening
- (vi) Operation of unit at no load – check run out of rotating parts, behavior of various bearings, setting over speed trip device
- (iv) Operation of unit at part loads and full load – check run out of rotating parts behavior of various bearings, check vibration, pulsation and noise
- (viii) Output and guide vane and runner blade opening relationship
- (ix) Load rejection tests at 50%, 75% and 100% load
- (x) Check proper operation of all turbine auxiliaries
- (vi) Tests for meeting performance guarantee

## 6.9.3 Inspection for cavitation pitting

It is to be ensured that operating records during guarantee period are properly maintained. It is also to be verified that machines are operated within specified range of output head and discharge.

After specified period of running of machine joint inspection is to be carried for cavitation pitting and establishing that cavitation is within limits and ensure it meets the provisions of cavitation guarantee.

## 6.10 Technical Specification of Speed Increaser (Tubular or Pit Type Turbines)

### 6.10.1 General

A gear box of gear ratio suitable to match the turbine and generator shall be supplied. The speed increasing gear box shall be connected to the turbine and generator shaft

In low head schemes, turbines run at less than 400 rpm, requiring a speed increaser to meet the 750-1000 rpm of standard alternators. This solution being economical as compared to use a custom built alternator is preferred.

Normally speed increasers are classified according to the gears used:

- i) Parallel shaft using helical gear set on parallel axis, preferred for medium power applications.
- ii) Bevel gears commonly limited to low power applications using spiral bevel gears for a 90<sup>0</sup> drive. It is a two phased speed increaser. The first is a parallel gear box and the second a bevel gear drive.
- iii) Belt speed increaser that is commonly used for small power application.

## **6.10.2 Technical Requirements**

The gear box should be designed for most unfavorable conditions, the correct alignment of its components. These are fabricated in welded steel with heavy stiffeners to resist the turbine torque and hydraulic axial thrust without apparent deformation.

The speed increaser should incorporate a torque limiter, so that connector breaks when there is abnormal force. A lack of synchronism, full load rejection, or any other accident in the system can generate very high critical stresses on gears.

To ensure the required level of reliability, good lubrication is essential. It is very important that the quality, volume, viscosity and the temperature of the oil is as per standards. A double lubrication system with two oil pumps and two oil filters is preferable for system reliability.

Design of Speed increaser shall conform to International standards GMA: 2001, B: 88 or DIN: 3990 using very conservative design criteria.

The gear box shall be designed to be capable of with standing continuous run way operation and shock loads due to load variation and due to pressure pulsations in the turbines. The gear efficiency shall be as high as possible and shall be considered in evaluation of the turbine efficiency for purpose of Bid evaluation

Thorough analysis of fatigue strains, careful shaving of heat treated gears, stress relieving of welded boxes is essential to ensure durability of speed increaser.

Metallurgical factors, hard casing or plasma nitriding of gears are essential to optimize the speed increaser.

Literature, leaf lets showing general arrangement of gear box, factor of safety, capability to with stand shock loads, cooling & lubrication arrangement, temperature indication, bearing arrangement, app. weight, dimensions, past experience reports etc. shall also be supplied with offer. If thrust bearing is installed in gear box then its details, drawings, information on temperature detection etc. shall be furnished.

## **7.0 TECHNICAL SPECIFICATIONS FOR GOVERNING SYSTEM**

### **7.1 Scope**

The scope under this section should include design, material selection, manufacture, shop assembly and testing, transportation and delivery to site, installation, commissioning, field acceptances test, warrantee and other services as specified or required.

### **7.2 Major Components for Governor**

These shall be as follows:

- Digital controller
- Speed signal generator (SSG)
- Servomotor feedback system

- Centrifugal type over speed switch
- Oil pressure unit
- Oil piping

### **7.3 Operating Duties**

- Francis turbine - To control guide vane opening and closing
- Kaplan turbine - To control guide vane and runner blade opening and closing and their synchronized operation
- Propeller turbine - To control guide vane opening and closing
- Semi Kaplan - To control runner blade opening and closing
- Pelton turbine & Turgo impulse - To control water jet through needles and deflectors and their synchronized operation

### **7.4 Performance Guarantees for Governor (as per IEC: 60308-1970)**

Performance Guarantees shall be in accordance with the provisions of IEC: 60308-1970.

### **7.5 Digital Governor**

It should be PID type microprocessor based digital governor complete with actuator, oil pressure vessel, sump tank, oil pumps, leakage oil tank, piping, control and indicating devices speed signal generator and other electrical / electronic equipment suitable for automatic control of all parts and accessories required to make complete operating unit for regulating the speed and load. The governor should be designed for controlling the unit in a stable manner at all out puts between zero and maximum when the generator is operating in parallel with other generators in grid or as isolated load.

The electrical equipment and hydro mechanical equipments of the governor shall be arranged in separate cubicles. The control system shall be suitable for 110/ 220 V AC and 24V DC.

The governor shall regulate turbine to uniform speed free from hunting or instability throughout its operating range. Governor should be able to provide:

- Accurate and stable setting at base load
- Load/ frequency control with high regulating capacity
- Rapid regulation in the event of system disturbances.
- Stable regulation during no load operating.
- Great stability of setting and function
- The speed dead band at the rated speed should not exceed 0.2%.
- For sudden load change of more than 10% of turbine capacity, the governor dead band time shall not exceed 0.2 second.

## 7.6 Constructional Features

The governor shall have the following features

- (i) It shall be suitable for automatic electrical control from Unit sequencer panels and also to provide indication at the control panels to regulate the turbine to a uniform speed free from hunting or instability at all loads.
- (ii) Suitable means shall be provided in the governor for full opening of the guide vanes during the turbine start up conditions, if auto synchronizer is provided in unit controller.
- (iii) It shall be provided with a set of control gear to be mounted on governor cubicle and or unit-control board to provide one control station and shall include
  - (a) Speed/ load setting
  - (b) Gate limit setting
  - (c) Start / stop push buttons
  - (d) Speed indicator and or runner blade
  - (e) Gate position and limit indicators
  - (f) Speed relays to initiate automatic start and stop control functions
  - (g) Feature for load/ frequency control from load dispatch
  - (h) Emergency shutdown.
- (iv) The governor shall be fail-safe on failure of the speed sensing element, loss of oil pressure or defect in actuating system, so that under any of loss of oil pressure, defect in actuating system, the machine shall be automatically shut down and shall initiate alarm and indication.
- (v) The governor shall be designed for independently adjusting the opening and closing rates of movement of turbine wicket gates for full gate opening or closing stroke. A secure and rigid means shall be provided for locking the rate of adjustment.
- (vi) The governor shall be provided with a set of the restoring mechanism of transmitting guide vane servomotor movement to the distributor valve/ control valve.
- (vii) Speed adjustment over the range of 85% to 115% of the rated speed along with the indicator.
- (viii) An automatic shut down device for complete closure of guide vane. The operating solenoid shall be of self-latching type with the provision of electrical reset.
- (ix) Indicating lamps for showing the position of locking mechanism
- (x) Any other devices, which may be required for satisfactory operation of the governor.

## 7.7 Governor Oil Pumping Unit

Governor oil pumping unit shall consist of a oil sump tank with oil pumps, valves and fittings mounted on it.

### **7.7.1 Oil sump tanks**

The oil sump tank provided shall be of sufficient capacity with necessary margin to hold all the oil in the governing system of the turbine and keep the operating temperature at lower level. The governor oil sump tank shall be provided with gauge glass type level indicator, level switches for low/ high oil level alarm, oil filter, air vent and oil inlet/ outlet connection and drain valves etc.

### **7.7.2 Oil pumps**

Governor shall be provided with independent motor driven oil pumps, of sufficient capacities to fulfill the requirements of the governor oil pressure system with a stand by governor oil pump. The two pumps shall be interconnected so that they can be operated independently or together. The governor oil pump shall be self priming, under the minimum oil pressure and shall be driven by motors of continuous duty. Each pumping unit shall be provided with unloader valves, check valves, safety valves, suitable number of hand operated valves, fitting and interconnecting pipes etc., so as to make the pumping unit complete in all respects and shall have noise level below 80 dB.

### **7.8 Oil Pressure Vessel/ Accumulator**

- The pressure tank shall be constructed in accordance with relevant IS or any equivalent standard. The pressure tank must have sufficient capacity for two - three complete operations (COC) of all servomotors of the turbine. The oil requirement shall be indicated. Hand shut off valves at the bottom of the tank and automatic arrangement for shutting of oil and air discharges shall be provided.
- The oil pressure vessel shall be provided with the following safety / control / operation switches:
  - (a) Pressure/ differential pressure switches for automatic starting & stopping of oil pump and for alarm and tripping the units under low and very low load, low pressure conditions respectively.
  - (b) Level switches for giving alarm and shutting down the machine when oil level falls below pre determined level.
  - (c) Level switches for giving alarm when oil level rises above a predetermined level.
- The oil pressure accumulator shall be equipped with an oil level gauge with automatic valves at the ends for preventing air and oil loss in case glass breaks.
- The oil pressure unit shall be complete with air inlet, air relief valve (safety valve), pressure gauge, oil drain connection with valves, manholes etc.

### **7.9 Nitrogen Charged Accumulator**

- Nitrogen charged piston type pressure accumulator with adequate nitrogen filled bladders assembled in the metal cylinders should be provided for each turbine separately for the governor oil pressure vessel when operating oil pressure is beyond 40 kg/ cm<sup>2</sup>.

- The capacity of the system shall be sufficient to cater each turbine unit, brakes etc. the system shall be so designed to cater two to three complete operations for guide vane and one operation of MIV without the need of recharging the accumulator by starting OPU with necessary pumps piping, safety devices, fittings, control valves, pressure gauges etc.

## 7.10 Governor Oil Piping and Valves

The governor oil piping and valves complete with flanges, bolting materials, gaskets, packing etc., required for inter-connection between the various equipments shall be included. All piping shall be of steel, suitable for maximum governor oil working pressure. All valves shall be of cast or forged steel having flanged ends.

## 7.11 Governor Oil

The oil for the first filling of the hydraulic system of turbine plus twenty percent extra, in non-returnable drums shall be included in the scope of supply.

## 8.0 TECHNICAL SPECIFICATIONS FOR SYNCHRONOUS GENERATOR

### 8.1 Scope

This section should include design, manufacture, tests at works, transportation, delivery at site, site storage, erection, testing and commissioning, complete with accessories, fittings, instruments, auxiliaries, safety devices, and spares for five years operation. The scope of supply should include all parts accessories and spare etc. which are essential for construction, operation & maintenance even though these may not be stated individually in these specifications. Inter-changeability of components of the generators and associated equipment must be ensured.

The generator manufacturer shall coordinate with the turbine supplier for matching in respect of coupling, speed, runaway speed, moment of inertia, overload capacity and other relevant requirements.

### 8.2 Type of Rating

The synchronous generator should be horizontal/vertical shaft, hydro turbine driven, alternating current type, suitable to operate in parallel with nearby grid. The direction of rotation shall be matching with turbine. The rating shall be given in the following table.

S. No.	Description	Rating
(i)	Rated capacity at rated voltage and rated power factor	: kVA
(ii)	Maximum (continuous) capacity at rated voltage and rated power factor	: kVA
(iii)	Number of poles	: Nos.
(iv)	Rated generation voltage	: kV
(v)	Rated power factor	: Lag
(vi)	No. of phases	: Three

(vii)	Rated frequency	:	50 Hz
(viii)	Variation	:	a) Voltage... -5 to +5 % b) Frequency... -3 to +3 %
(ix)	Stator winding	:	Star connected with suitable grounding
(x)	Direction of rotation	:	matching with turbine
(xi)	Suggestive speed of generator	:	..... r.p.m.
(xii)	Moment of Inertia	:	.....kg/cm <sup>2</sup>

The stator winding shall be star connected and the main and neutral leads shall be brought out through adequately rated XLPE Cables.

Rating, tests and characteristics shall be in accordance with latest IEC/IEEE standards ANSI C 50.12-2006 and IEEE No 115-2009.

The generator shall be designed in accordance with best international practice, with liberal factor of safety and for continuous operation at 110% rated kVA at rated voltage, power factor and frequency.

### 8.3 Speed Rise, Runaway Speed and Critical Speed

The combined moment of inertia (turbine, gearbox, generator) should be such that maximum momentary speed rise under governor control on full load rejection shall not exceed 45% of rated speed for the grid connected generator.

The maximum runaway speed and critical 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 at least 15 minutes without any damage to any part. The guide bearing and guide cum thrust bearing of machines above 3 MW capacity shall be capable to withstand runaway speed for 15 minutes without supply of cooling water and 30 minutes with cooling water without abnormal temperature rise and increase of vibration. However for machines up to 3 MW guide bearings and guide cum thrust bearing shall be capable to withstand runaway speed continuously with cooling water.

### 8.4 Noise Level

The noise level shall not exceed 85 dB (A) when measured at a distance of 1 m from any component of generator.

### 8.5 Insulation & Temperature Rise

Insulation material for stator winding shall be class 'F' or above. Insulation shall have high basic insulation level suitable to withstand system surges on account of switching surges and lightning surges.

The generator shall be capable of delivering rated output continuously at any voltage and frequency in the operating range at rated power factor without exceeding the following values of temperature rise over ambient temperature.

- a) Stator winding 70<sup>0</sup>C
- b) Rotor winding 80<sup>0</sup>C
- c) Stator core 65<sup>0</sup>C

The temperature rises shall be guaranteed and shall be measured at site in accordance with IEC 340 or relevant Indian Standard.

### 8.6 Efficiency and Output Guarantees

Within the limit of temperature rises specified above, the rated continuous output of the generator shall be guaranteed under penalty with a rejection limit of minus 2% for the rated terminal conditions.

The weighted average efficiency of the generator shall be guaranteed under penalty with a rejection limit of minus 2%. The efficiency shall be determined by summation of losses method as specified in latest IS 4889. For any short fall in the test value of output and weighted average efficiency from guaranteed figures, the penalty shall be @5 % of ex-works value of generator for every 1% fall by which test figure is less than the guaranteed figures. The weighted average efficiency  $\eta_{g(AV)} = 0.1\eta_{g110} + 0.5\eta_{g100} + 0.25\eta_{g80} + 0.15\eta_{g60}$

The penalty for output and efficiency shall be computed separately and the total amount of penalty shall be sum of two.

The ceiling on the total amount of penalty on account of shortfall in weighted average efficiency and output will be mutually decided by the purchaser and the supplier.

No tolerance would be permitted over test figures of output. Tolerance in determination of efficiency shall be as per relevant Indian Standard.

### 8.7 Electrical Characteristics

Following principle characteristics should be given in this paragraph.

- (i) Rated continuous rating at rated power factor and at : ..... kVA  
normal rated terminal voltage
- (ii) Continuous over load capacity : 10 %
- (iii) Minimum terminal voltage (operating continuously with : 5% lower than  
uploaded system) normal rated voltage
- (iv) Excitation at maximum leading kVA expressed as : Not less than .....  
percentage of that required at rated output and power factor %
- (v) Terminal voltage at which the maximum continuous rating : 10 % higher than  
must be achieved normal rated voltage
- (vi) Short circuit ratio on rated kVA base, not less than : 0.9
- (vii) Total Harmonic Factor (THF) : 3%
- (viii) Deviation factor of wave form measured in percent of open : .....  
circuit at rated voltage & frequency, not more than
- (ix) Efficiency at rated kVA, rated power factor and normal : ..... %  
rated output
- (x) Normal exciter response for the exciter, not less than : 2
- (xi) Ceiling voltage of exciter when connected to generator : To suit above

- (xii) field and with rated exciter current deliver (80°C)  
Line charging capacity of the generator when charging a : ..... kVA  
transmission line at rated speed and voltage without being  
completely self excited or unstable, not less than
- (xiii) Maximum ambient air temperature : ..... °C
- (xiv) Inertia constant : .....

**8.8 Mechanical Characteristics**

- (i) Minimum Flywheel effect (GD<sup>2</sup>) of rotating parts of : .....  
generator & exciter
- (ii) Direction of rotation : To match Turbine
- (iii) Max. run away speed : To match Turbine
- (iv) Max. temperature at inlet of cooling water for air : ..... °C  
cooling system
- (v) Design mechanically to withstand continuous over load : ..... kW  
(kW) at 1.0 power factor continuously with out  
exceeding the specified normal operating stress and any  
mechanical damage to the generator
- (vi) Design mechanically to withstand temporary overload, : ..... kW  
with stress not exceeding one and half the yield point  
corresponding to turbine output of not less than  
(provided the duration of such overload does not cause  
injurious heating)
- (vii) Designed for operation with a hydro turbine having : ..... kW  
rated output

**8.9 General Arrangement and Constructional Features (for example)**

**(i) Stator**

Stator frame shall be of fabricated steel construction. The frame shall be designed to with stand bending stresses and deflections due to its own weight and weight of the complete core to be supported by it.

The stator core shall be built up of single piece segmental punching of low loss, non oriented steel sheets and end plates. Each punching shall be carefully deburred and insulated on both side with high quality varnish to reduce losses in the core.

The stator winding shall be of multi-turn or single turn type and shall be insulated with class ‘F’ insulation system conforming to latest version of IEC 60085-2007 or relevant Indian Standard. The stator winding shall be star connected with both ends of conductor of each phase brought out of the stator and terminated in suitable terminal box. Six numbers embedded type temperature detector of resistance type shall be provided for stator winding located symmetrically.

It should be possible to replace windings at site and the insulation system slots and winding arrangement shall be designed to this end. Full details of method equipment and components required for replacing coils shall be included in operation and maintenance manual and outlined in the tender.

The stator casing should be provided with adequate lifting eye bolts. If the generator is horizontal and stator is required to be jacked to allow the rotor to be removed then brackets shall be provided for use with hydraulic jacks.

**(ii) Rotor**

The design and construction of rotor shall be in accordance with the best modern practice. The factor of safety at maximum runaway speed based on yield point of material shall not be less than 1.5.

Any special lifting gear such as beams or special slings supports which are necessary to remove or replace the rotor shall be provided. The proposed method of rotor removal shall be described in the tender.

Field winding shall be insulated with class 'F', insulation and shall consist of fabricated copper strips. The field winding shall be adequately braced to withstand all mechanical stresses imposed during maximum runaway speed. The field poles shall be provided with adequate damper winding to ensure suitability under fault conditions.

**(iii) Fans**

The generator shall have a closed circuit or open circuit system of ventilation depending on capacity of generator. The air shall be circulated through the closed system by combined action of rotor poles. If required suitable axial flow/ centrifugal fans shall be provided at both ends of rotor to have effective air cooling system.

**(iv) Shaft**

The generator shaft shall be made of high quality Manganese steel forging; properly heat treated and shall be accurately machined all over and polished at the bearing surfaces and at accessible points for alignment checks. An integrally forged flange shall be provided at the shaft for coupling with turbine directly or through gearbox. The shaft shall be of adequate size and strength to operate at all speeds including maximum runaway speed and shall be able to withstand short circuit stresses with excessive vibration or distortion.

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 of horizontal sets of capacity less than 1 MW shall be checked at supplier's works in accordance with International Standards IEEE 810-1994 in the presence of Purchaser's representative and the run out values shall not exceed tolerances specified in the above Standards.

**(v) Bearings**

The generator bearings can be of:

A. For Horizontal machines

- (i) Pad type or sleeve type having babbit metal lining. Oil, grease lubricated or self lubrication or forced lubrication type
- (ii) Anti friction ball/ roller bearings oil or grease lubricated type (for small horizontal machines.)These bearings shall be guaranteed for continuous working for 1, 00, 000 hours (one lac hours) and shall be of proven design and performance

**B. For Vertical machines**

- (i). Thrust bearing-pad type having babbit metal lining. Oil, grease lubricated or self lubrication or forced lubrication type
- (ii). Guide bearing- pad type/sleeve type having babbit metal lining. Oil, grease lubricated or self lubrication

Bearings shall be adequately insulated to prevent any harmful circulating currents. Thrust bearings shall be suitable to take axial thrusts in both the directions. The bearings shall be designed to withstand operation of runaway speed for a period of 30 minutes with cooling water ON and 15 minutes with cooling water OFF, if cooling water system is provided. Thermometers, pressure gauges, flow relays, etc., as required, shall be provided.

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

Dial type thermometers complete with two independent settable contacts making for alarm and trip temperatures and hand resetting of maximum temperature indicator shall be provided for each bearing and shall measure bearing shell or pad temperatures as close to the lining to journal or thrust ring interface as practicable. Water cooled bearings shall have high or low water level trip contracts.

**(vi) Ventilation**

The generator shall be provided with screen protected enclosure as per IP:23 for open ventilated type machines. It is necessary to prevent dust and rubbish entering the machine when it is shut down, the air outlets shall be fitted with self opening louver ventilators or equivalent.

**(vii) Generator Heaters (Wherever Applicable)**

Space heaters of adequate rating shall be provide for maintaining stator winding temperatures at least 5°C above ambient temperature during prolonged shut down periods.

The leads from heaters shall be brought to clearly labeled terminal box in an accessible position.

**(viii) OIL & GREASE**

Oil, if used for lubrication of generator bearing etc shall be identical with that to be used for governor pressure oil system and turbine guide bearing. The first filling of oil / grease with 20% extra shall be supplied along with generator.

## **8.10 Excitation System & AVR**

Excitation system may be any of the following two types

- (i) Brushless digital excitation system having AC exciter with rotating diodes, AVR & APFC. Power for AVR is provided by main generator terminals. (For machines up to 15 MW capacity).
- (ii) Static excitation system where Thyristor based rectifier converts AC to DC and feeds generator field directly. Power for excitation system is drawn from generator terminal. Exciter transformer with associated fuses and accessories is used for this purpose. AVR & APFC are also provided for voltage regulation and power factor control. ( For machines above 15 MW capacity)

### **8.10.1 Technical specification of brushless excitation system**

Generator shall be equipped with brushless digital excitation equipment with adequate redundancy for trouble free operation of Generator. The equipment shall conform to the latest designs and applicable standards. The excitation system shall permit continuous stable operation of the generator under manual excitation control or automatic voltage regulator control for all conditions of operation. The voltage regulating and excitation control equipment shall be suitable for control from the Excitation panel in the control room. The excitation system shall be complete with devices for trouble free and efficient operation including indication, protection alarm and control devices even though some items are not described here.

#### **8.10.1.2 Excitation system**

The Brush less excitation system comprises of mainly

- a. Alternating current Exciter
- b. Rotating Rectifier Bridge
- c. Voltage sensing transformers
- d. Automatic voltage regulator
- e. Auto power factor controller etc.

##### **a. AC Exciter**

The AC exciter is a salient pole 3-phase alternator whose armature is housed on the generator rotor and the field winding on the generator stator. The field winding is fed through an AVR, which derives power from the generator terminals by an excitation transformer and feedback voltage through a voltage-sensing transformer connected to the generator terminals. The AC generated by the Exciter rotor is fed to the rotating rectifier bridge and converted to the DC and fed to the Generator field directly.

##### **b. Rotating Rectifier Bridge**

Each unit will be provided with two rotating rectifier Bridges with 100% redundancy for supplying excitation power to the Generator. The rectifier bridge shall be provided with a voltage dependent resistance for protection against induced voltages. The rectifier elements

shall also be protected by snubber circuit with RC elements or any equivalent system as per latest practice from voltage spikes.

**c. Cubicles**

All the equipment of Brushless excitation and AVR shall be suitably housed in sheet metal, dust proof cubicles. All these cubicles shall be located at one place in a row without any gap in between. The dimensions (depth, height, etc.) and outside appearance of the cubicles shall be identical to present a neat and functional line up. The overall appearance shall also match with the other group of panels like unit control panels, protection panels, etc. These cubicles shall be of self-cooled type without provision for any external cooling fans.

**8.10.2 Technical specification of static excitation system**

**8.10.2.1 General**

The excitation system of static type consisting of high performance fully controlled solid state converter bridge, dry type excitation transformer of suitable capacity, static voltage regulator, field breaker, field flashing unit, field discharge resistor, etc., conforming to acceptable relevant international standards may be supplied. The excitation shall be completely described in the tender.

**8.10.2.2 Excitation transformer**

- i. The Excitation Transformer shall be three phase dry cast resin coil type transformer connected to generator terminals by XLPE Cable shall be of suitable size and adequately rated. The transformer shall be designed and manufactured in accordance with relevant latest standard and shall be housed in a cubicle.
- ii. The transformer shall be sized such that it supplies rated excitation current at rated voltage continuously and shall be capable of supplying ceiling current at the ceiling excitation for a short period. The bidder shall furnish the calculation for sizing the excitation transformer. The rated field current and field voltage shall suit the requirement of the Generator. The transformer shall be self-cooled, indoor, enclosed dry type. Since the high voltage winding is connected directly to the generator terminals, full design consideration shall be given to the generator frequency increase rate, generator voltage build up rate, generator fault level and insulation co-ordination. Surge transmission from the high voltage side to the low voltage side shall be prevented by suitable means. Full rated capacity taps on the high voltage winding shall be provided to accommodate the complete range of operation. The transformer shall have taps of +5%, +2.5%, -2.5% and -5% on HV side.
- iii. The high voltage and low voltage windings shall be of copper conductors. The transformer shall be equipped with a winding hot spot temperature detector of the resistance type together with necessary accessories arranged for remote indication. The detector shall be suitable for use with the temperature recorder. The 11 kV terminations of the transformers shall be suitable for connection with 11 kV XLPE cable. The low voltage terminals shall be suitable for terminating LT copper cable of suitable size. The transformer shall be housed in a cubicle with IP-20 protection.

- iv The transformer shall be completely assembled at the factory and shall be subjected to standard type and routine tests. Dielectric tests and other tests shall also be carried out at site. The transformer shall be provided with the protections.
- v Calculations justifying the rating of the transformer selected shall be furnished in the bid and the same is subject to the approval of the Employer. The transformer shall be suitable for the fault current of Generator on HV side, which shall be indicated in the bid with calculations.

### **8.10.2.3 Generator field discharge equipment**

A totally enclosed field air circuit breaker, draw out type, complete with auxiliary contacts, capable of breaking, without generating dangerous over voltage, the maximum field current that can occur under conditions of normal operation or when interrupting the transient D. C. component of the field current due to a three-phase fault at generator terminals, shall be furnished with each set of excitation equipment. The field circuit breaker shall be suitable for both manual and electrical operation. Alternatively, an A. C. circuit breaker on the secondary side of the rectifier transformer instead of D. C. field circuit breaker may be offered.

The field circuit breaker discharge contacts, discharge resistors, or other equipment shall be mounted together to form a self-supporting assembly of the excitation control equipment of each generator. A suitable hinged door, locking handle, inspection windows, foundation bolts etc., shall be provided with each excitation cubicle.

### **8.10.3 Automatic voltage regulator**

#### **8.10.3.1 General**

The voltage regulation class of accuracy and performance shall conform to the latest version of relevant Indian Standard.

The voltage shall be maintained within + 5 % to – 5 % of rated voltage – under steady state conditions for all loads without hunting between no load to full load at rated power factor on isolated load conditions.

The AVR shall be capable of preventing an excessive over voltage during over speed conditions following loss of load. The voltage shall not rise above 110% of normal after shedding full rated kW load at the rated power factor with normal speed rise. This may be achieved by an over voltage relay tripping the field switch.

During change over from auto to manual and vice versa there should be no dip in generator voltage.

If an exciter output over voltage condition persists for sufficient time such condition shall be able to initiate the following action

- (a) The generator lockout relay shall be tripping to shut down and lock out the generator along with excitation system.
- (b) Provide annunciation.

The AVR shall be suitable for operating with automatic synchronizing equipment.

The excitation system shall incorporate the following features and facilities

- (i) Manual voltage setting rheostat
- (ii) Protection against AVR failure (e.g. over / under excitation combined with over/ under voltage)
- (iii) Each fault monitoring unit shall be provided with contacts for indication of the alarm / annunciation on AVR and excitation panel.

### **8.10.3.2 Regulator and sequencing control**

#### **8.10.3.2.1 Regulator**

For ease of maintenance and to minimize “Time to Repair”, the regulator shall be an assembly of card file mounted plug-in type printed circuit cards. Test points shall be provided on the front of each card so that circuit checks can be readily made while the equipment is operational. In addition, the card field assembly shall be front door mounted so that it shall not be necessary to open a cubicle door to make the regulator circuit checks.

Alternatively, the regulator may be PLC based digital. For small machines up to 10MW, the functions of regulator may be performed in main PLC controller.

The following functions shall be provided.

#### **8.10.3.2.2 Power factor and voltage regulators**

In the “Power Factor” mode, the reactive component of generator current shall be compared to an adjustable DC reference and the amplified error signed shall be used to drive a motor operated potentiometer which raises or lowers the voltage regulator set point, thereby changing field excitation to obtain required reactive current loading. The “Power Factor” regulator shall maintain the reactive current ampere loading on the generator within  $\pm 5\%$  without hunting under steady load conditions when the system voltage deviation does not exceed  $\pm 10\%$  from nominal.

The operation of the regulator, when in the “Power Factor” mode, shall automatically switch into the “Voltage” mode whenever the unit breaker is open. Thus during the synchronizing period of time, the synchronizer can be used to drive the motor operated potentiometer to adjust the terminal voltage to the required condition for synchronizing.

In the voltage mode, the average generator three phase terminal voltage adjustable DC reference and the amplified error signal applied to the excitation system to maintain the terminal voltage with  $\pm 0.5\%$  without hunting under steady load from no-load to full load condition. The range of control shall be from 10% below normal to 10% above normal generator voltage.

The “Power Factor” and “Voltage” regulator shall include reactive droop compensation.

#### **8.10.3.2.3 Field current regulator**

The “Field Current” regulating mode shall provide a back-up system for the “Power Factor and “Voltage” regulators. In this mode, the generator terminal voltage (kVAR loading)

shall be under the operator's manual control. Variations in system voltage which effect kVAR loading must be compensated by readjustment of the "Field Current" regulator "Set Point" adjust. The range of control shall be from approximately 10% less than no-load field current to approximately 5% above maximum required field current.

Maximum Excitation Limiter (Operational and "Power Factor" and "Voltage" Regulating Modes Only).

- (i) Selection of "Power Factor", "Voltage", and "Field Current" regulating modes shall be via remote/local control. The control shall permit transfer when the unit is on line.
- (ii) Local/Remote control of "Set Point" adjust for the "Power Factor" and "Field Current" regulators. The "Power Factor" regulating mode shall be the normal operating mode.
- (iii) Provide minimum excitation limiter to automatically limit the decrease of generator excitation. The limiter shall hold the generator field current at a preset value determined from the reactive capability curve of the generator.
- (iv) Provide maximum excitation limiter to limit the field current after an adjustable time delay to prevent sustained field over current. The time delay shall be inversely proportional to rate of change in field current. An instantaneous over current limiter shall be included to prevent excitation from exceeding ceiling current.

## **8.11 Spares**

The tenderer shall provide a list of required spares for five years satisfactory operation & maintenance and furnish item wise unit prices for the same. Alternatively the list of spares may be prepared and annexed to the tender document by the purchaser.

## **8.12 Generator Test Schedule**

### **1. Tests at Manufacturer's Works**

The generator shall be completely assembled at works and type and routine tests as specified below shall be conducted on the assembled unit and auxiliaries as per the latest edition of relevant Indian Standard or IEC in the presence of Purchaser's representative.

#### **A. Type Test**

- (i) Temperature rise test
- (ii) Dielectric test
- (iii) Efficiency test
- (iv) Excess current test
- (v) Runaway speed test subject to test plant capacity of manufacturer, otherwise at site
- (vi) Moment of inertia of rotating parts  
(By mutual agreement between purchaser & supplier)
- (vii) Wave form
- (viii) Various parameters and characteristics

- (a) Reactance synchronous, transient, sub transient negative phase sequence and zero phase sequence
- (b) Rated current, zero power factor, lagging saturation curve.
- (c) No load and short circuit saturation curve

## **B. Routine Tests**

- (i). High voltage test on stator coils and stator section and assembled stator
- (ii). High voltage test on field coils and poles
- (iii). Insulation resistance tests
- (iv). Impedance and voltage test on field coils
- (v). Accuracy test for RTDs and dial type thermometers
- (vi). Routine test on excitation equipment
- (vii). Additional test, if any as recommended

## **2. Tests at Site**

Site test for each generator shall include

- (i) Mechanical run
- (ii) Measurement of stator and rotor winding insulation resistance (both before and after high voltage test as per type of excitation system)
- (iii) High voltage dielectric test ( as per type of excitation system)
- (iv) Measurement of shaft voltage
- (v) Measurement of stator rotor winding resistance ( as per type of excitation system)
- (vi) Phase sequence test
- (vii) Load acceptance & rejection test at selected loads from no load to full load
- (viii) Over all response of machine on system (grid) voltage changes
- (ix) Adjustment of AVR
- (x) Synchronizing test
- (xi) Check and commissioning various other auxiliary equipment
- (xii) Efficiency & performance test as per IS:4722-2006 & IEC -60034-2010

Besides above following checks/ test shall also be carried out.

- (i) Measurement of air gap between stator and rotor
- (ii) Alignment of generator rotor, turbine runner and shaft system with the help of dial gauges.
- (iii) Balancing of rotor and bearing run
- (iv) Dry out of stator winding
- (v) Braking test for verifying stopping time
- (vi) Rotor and stator form subject to recommended tolerances
- (vii) Measurement of magnetic centre to be within tolerances( 0.2 to 0.5 depending on length of shaft) if rotor and stator assembled at site
- (viii) Test to determine following
  - (a) Open circuit test
  - (b) Short circuit characteristics
  - (c) Direct axis synchronous impedance
- (ix) Determination of the balanced and residual component of telephone interference factor

- (x) Test for deviation factor in wave form
- (xi) Hydrostatic pressure tests on all oil, air and water coolers and associated piping for a period of not less than one hour (Test pressure to be indicated in bid).
- (xii) Run away speed test for 2 minutes

#### **8.12.1 Testing equipment**

All testing equipment shall be provided by the supplier for carrying out above tests successfully and completely.

In the event repeated tests becoming necessary the entire expenditure on such tests shall be borne by the supplier.

#### **8.13 Special Tools**

The bidder shall include a complete set of special tools and other devices that may be necessary or desirable for erection, operation & maintenance of generator and auxiliary equipment.

#### **8.14 Erection, Testing & Commissioning**

The supplier shall depute experts during erection testing and commissioning of generator and associated auxiliary equipments and hand over to the satisfaction of purchaser.

#### **8.15 Drawings and Documents**

The following drawings and data sheet shall be furnished with the tender

- (i). General arrangement and over all dimensions of generator, bearings and showing position of main and neutral terminals
- (ii). Description of lubrication system along with drawings
- (iii). Graphs showing various standard characteristics of generator
- (iv). Generator layout drawings showing overall dimensions and layout of all ducts
- (v). Loads & moments during short circuit to enable civil foundation design
- (vi). Details and drawings of foundation frame

#### **8.16 Miscellaneous Accessories**

The generator shall be supplied with foundation frame, sole plates, foundation bolts, jack bolts and pads for on site erection and alignment. Two earthing terminals shall be provided for earthing the generator. The generator shall be provided with lifting hooks to unload and handling at site.

### **9.0 TECHNICAL SPECIFICATIONS FOR INDUCTION GENERATOR**

#### **9.1 Scope**

This section should include design manufacture tests at works, transportation, delivery, insurance, storage, erection, testing & commissioning, complete with accessories,

fittings, instrumentation, auxiliaries, safety devices, and spares for five years operation. The scope of supply should include all parts, accessories and spare etc. which are essential for construction operation & maintenance even though these may not be individually stated in these specifications. Interchangeability of components of the generator and associated equipment must be ensured.

The generator manufacturer shall coordinate with the turbine supplier for matching in respect of coupling, speed, runaway speed, moment of inertia, over load capacity and other relevant requirements.

## 9.2 Type & Rating

The induction generator should be of horizontal or vertical shaft, hydro-turbine driven, and alternating current type suitable to operate in parallel with nearby grid. The direction of shall be matching with the turbine. The ratings shall be as follows.

S. No.	Description	Rating
i.	Rated output (kW)	.....
ii.	Power factor (lag)	.....
iii.	Frequency (Hz)	50Hz
iv.	No. of phases	3
v.	Rated terminal voltage (between phases)	.....
vi.	Range of voltage variation	±5%
	Frequency variation	±3%
vii.	Stator winding connection	.....
viii.	Rated speed (RPM)	.....
ix.	Continuous over load and capacity over & above rated output	+ 10%
x.	Inertia quotient	.....
xi.	Direction of rotation	.....
xii.	THF	AS per IS

The generator shall be capable of delivering continuous 110% of rated output at rated power factor with class B temperature rise.

The generator shall be connected directly or through speed increaser.

The generator shall be star connected and three mains and neutral leads shall be brought out of the stator frame and terminated inside the respective cable box of appropriate size on stator frame. The generator neutral shall be suitably grounded.

The generator shall be designed to safely withstand any mechanical or magnetic stresses resulting from either a three phase or a single phase fault occurred at generator terminals for three seconds when operating at maximum out put, rated power factor and 10% over voltage.

The generator shall conform to the latest issue of IS: 325-1978/4722-2007 or equivalent International Standard.

The rating plate shall be in accordance with IEC: 60034-2010 or relevant IS and shall be engraved on stainless steel plate/ brass plate. All other labeling should be black engraved writing on white labels attaché by screws to the appropriate equipment or terminal block.

### **9.3 Reactive Power**

Suitable capacitor banks should be utilized to meet reactive power requirement for no load and full load running operation. Reactive power requirement of generator VAR's should be intimated so as to ascertain capacitor, bank capacity and its arrangement accordingly.

### **9.4 Speed Rise and Runaway Speed**

The combined moment of inertia (turbine, gearbox & flywheel) should be such that maximum momentary speed rise shall not exceed 45% of rated speed to avoid excessive stress in generator.

The generator shall be designed and constructed in such a way that it may run safely for 30 min. on runaway speed. The runaway speed test may be carried out at site after ensuring suitability of generator foundations.

### **9.5 Noise Level**

The noise level shall not exceed 85 dB(A) when measured at a distance of 1 m from any component of the generator stator.

### **9.6 Insulation & Temperature Rise**

Insulation material for stator winding shall be class 'F' or above. Insulation shall have high basic insulation level suitable to withstand system surges on account of switching surges and lightening surges.

The generator shall be capable of delivering rated output continuously at any voltage and frequency in the operating range at rated power factor without exceeding limit of temperature rise for class B insulation over ambient temperature as per relevant Indian Standard

The maximum temperature rise, when generator is delivering maximum output corresponding to continuous overload capacity, if given for conditions stated, shall not exceed 90°C for stator and rotor winding.

The temperature rises shall be guaranteed and shall be measured at site in accordance with IEC 340 or relevant Indian Standard

### **9.7 Efficiency and Output Guarantees**

Within the limit of temperature rises specified above, the rated continuous output of the generator shall be guaranteed under penalty with a rejection limit of minus 2% for the rated terminal conditions.

The weighted average efficiency of the generator shall be guaranteed under penalty with a rejection limit of minus 2%. The efficiency shall be determined by summation of

losses method as specified in latest IS 4889-2007. For any short fall in the test value of output and weighted average efficiency from guaranteed figures, the penalty shall be @5 % of ex-works value of generator for every 1% fall by which test figure is less than the guaranteed figures. The weighted average efficiency  $\eta_{g(AV)} = 0.1\eta_{g110} + 0.5 \eta_{g100} + 0.3 \eta_{g80} + 0.1\eta_{g60}$

The penalty for output and efficiency shall be computed separately and the total amount of penalty shall be sum of two.

The ceiling on the total amount of penalty on account of shortfall in weighted average efficiency and output will be mutually decided by the purchaser and the supplier.

No tolerance would be permitted over test figures of output. Tolerance in determination of efficiency shall be as per relevant Indian Standard.

## **9.8 Cooling System**

The generator shall be natural air cooled self ventilated type provided with a cooling system based on open ventilation air circulation principle. The air passage in the stator, rotor and fans shall be designed to give smooth and quiet flow of air.

## **9.9 Generator Brakes**

The generator should be provided with pressure oil operated spring type brakes, which may be operated automatically or manually.

Pressure oil at required pressure will be made available from the turbine oil pressure system.

The brake should be capable to be applied at 30% speed and to retard the unit (runaway) to stand still within two minutes from the time when brake impulse is given. The brakes shall be provided with reliable limit position of brakes.

## **9.10 Fly Wheel**

Necessary flywheel effect shall be incorporated in the generator rotor for limiting the speed rise on load throw off. Supplier shall coordinate with turbine manufacturer for limiting the speed rise and pressure rise.

## **9.11 General Arrangement and Constructional Features (For Reference)**

### **9.11.1 Stator**

The stator frame is a rigid structure, designed to ensure correct distribution of airflow over the core & winding.

The stator core is built up of punching of low loss, non oriented silicon steel sheets and steel end plates. Each punching should be carefully deburred and insulated on both sides with high quality varnish to reduce losses in the core.

The stator slots are normally of semi-closed / half open in order to reduce losses.

The stator winding is of multi-turn type and shall be insulated with class 'F' insulation conforming to IEC 60085-2007 or relevant IS.

The stator winding is star connected and the terminal leads of each phase are brought out and terminated inside boxes of suitable size for power cable connection. Six nos embedded type temperature detectors of resistance type shall be provided for stator winding located symmetrically.

It is essential that it shall be possible to replace windings at site as such the insulation system, slots and winding arrangement shall be designed accordingly. The procedure of replacement of winding, tools tackles, spare components, consumable required shall be included in operation & maintenance manual and outlined in the offer.

### **9.11.2 Rotor**

The design and construction of squirrel cage type rotor shall be in accordance with best modern practice. The factor of safety at maximum runaway speed based on yield point of material shall not be less than 1.5.

### **9.11.3 Shaft**

The generator shaft shall be made of the best quality forged steel conforming to IEC 810 and shall be properly heat treated. The shaft shall be of adequate size to operate at all speeds including runaway speed and shall be able to withstand short circuit stresses without excessive vibration or distortion. The shaft shall be accurately machined all over and polished where it passes through the bearings and accessible points for alignment checks. The shaft shall have suitable provision for coupling directly to turbine or through gear box.

### **9.11.4 Bearings**

#### **A. For horizontal machines**

The generator shall be provided with antifriction ball/ roller grease lubricated bearings. The estimated bearing life should be around 1, 00, 000 hours.

Babbit lined sleeve type, oil / grease / self lubricated type of bearing may also be selected.

#### **B. For Vertical machines**

- (i) Pad type thrust bearing
- (ii) Pad type guide bearing

The bearing shall be adequately insulated to prevent harmful circulating currents.

In selection of bearings axial thrust internal to the generator is also taken into consideration. The bearings shall be designed to withstand against any damage, if the machine is operated continuously at runaway speed.

Dial type – bearing temperature detectors with trip and alarm contacts will be provided for bearings. The bearing shall be suitable to take its own thrust produced by the rotor.

#### **9.11.5 Fans**

Fan/ Fans shall be provided to meet ventilation requirement of the induction generator. Centrifugal fans may be mounted at both ends of rotor for ventilation purposes.

#### **9.11.6 Ventilation**

The generator shall be provided with screen protected drip proof enclosure i.e. IP 23/ SPDP protection as per IS-4691 or equivalent Indian Standard.

#### **9.11.7 Heater**

The generator shall be provided with adequate number of anti-condensation heaters suitable for single phase AC supply. Space heaters of adequate rating shall be provided for maintaining stator surrounding air temperature above the ambient during prolonged shut down period.

#### **9.11.8 Oil & greases**

The oil if used for generator lubrication etc. should be identical with that to be used for oil pressure system of Governor. The generator and turbine manufacture are required to coordinate with each other in this regard.

The first filling of oil / grease with 20 percent extra to be supplied along with generator.

#### **9.11.9 Power factor correction**

The generator should be designed to give designed power factor at full load.

#### **9.11.10 Capacitor bank**

Suitable capacitor bank (switched type) shall be provided to meet reactive power requirement of Induction generator. Capacitor bank of station type shall conform to IS: 2834 and shall be connected in parallel with the induction generator.

#### **9.11.11 Instruments, gauges and safety devices**

All instruments, gauges and safety devices considered necessary for satisfactory operation of the unit shall be supplied for mounting on unit control board and on the control room panels.

### **9.12 Spares**

The tenderer shall give a list of spare parts required for satisfactory operation of generator for 5 year and unit rate for the same shall be quoted by him. Purchaser may prepare his own list and ask for unit price for each item.

### 9.13 Tests

The generator will be completely assembled at works and type tests as specified below shall be conducted on one of the assembled units as per latest edition of IS:325-1978 / 4722-2007.

If test report for similar generator is available the same shall be submitted with offer.

- (i) Tests at Works
  - (a) Type Tests on First Generator
    - Temperature rise test
    - Momentary over load test
    - Evaluating the parameter and various load points
    - Estimation of pull out torque by calculation
    - Over speed test at maximum runaway speed  
(Shall be conducted on rotor during balancing)
    - Efficiency test on calibrated test stand as per standards
    - Check on physical dimension and general arrangement
  - (b) Routine Test on Individual Generator
    - Insulation resistance test before and after HV test
    - Reduced voltage run test on no load
    - No load running and checking voltage and current in three phases
    - Vibration at no load
    - Noise level on no load
    - Locked rotor test at reduced voltage
    - IR of space heaters and RTDs
    - Test certificate of accuracy of RTD, dial type thermometers and other bought out items
    - Additional test, if any
- (ii) Test at Site
  - Mechanical run
  - Measurement of winding insulation
  - High voltage dielectric test
  - Measurement of shaft voltage
  - Measurement of vibration and noise
  - Load acceptance and rejection test at selected loads from no load to full load
  - Output test to establish rated output
  - Checking and commissioning of other auxiliaries including tests as per applicable standard

The generator characteristic values for performance determination have to be arrived either through circle diagram method or equivalent circuit method after conducting required test on generator.

### 9.14 Testing Equipment

All testing equipment shall be provided by the supplier for carrying out above tests successfully and completely.

In the event of the repeated tests becoming necessary, the entire expenditure on such tests shall be borne by the supplier.

### 9.15 Special Tools

The bidder shall include a complete set of special tools and other devices that may be necessary or desirable for erection, operation and maintenance of the generator and auxiliary equipment.

### 9.16 Erection Testing and Commissioning

The supplier shall depute experts during erection, testing and commissioning of generator and associated auxiliary equipment and hand over to the satisfaction of purchaser.

### 9.17 Drawings & Documents

The following drawings and data sheets shall be furnished with the tender

- (i) The general arrangement and overall dimensions of generator, bearings and showing position of main and neutral terminals.
- (ii) Description of lubrication system along with drawings
- (iii) Graphs showing various standard characteristics of generator
- (iv) Generator layout drawings showing overall dimensions and layout of all ducts
- (v) Loads and moment during short circuit to enable civil foundation design
- (vi) Details and drawings of foundation frame

### 9.18 Miscellaneous Accessories

The generator shall be supplied with foundation frame, sole plates, foundation bolts, jack bolts and pads for onsite erection and alignment. Two earthing terminals shall be provided for earthing the generator. The generator shall be provided with lifting hooks to unload and handling at site.

## 10.0 TECHNICAL SPECIFICATION FOR MAIN INLET VALVE

### 10.1 Scope

This section of the specification deals with the design, manufacture, tests at manufacturers works before dispatch, supply, delivery to site, erection, testing at site, trail run and commissioning of Butterfly valves one each at the inlet of the Turbine capable of closing in the operating range under maximum discharge and including runaway condition conforming to IS: 7326-2008.

The following is the schedule of requirements covered under this section

S. No.	Name of the Equipment	Quantity for the project
1.	Butterfly valve with bypass valve, air admission valve, servo motor, inlet and outlet pipes, dismantling joint, control cabinet, instrumentation, erection and maintenance devices etc.	----sets

## **10.2 Type and Rating**

Butterfly valve of diameter matching with the penstock diameter shall be offered as turbine inlet valve. The valve shall be designed to open under balanced conditions and to close against maximum turbine flow from fully opened position by counter weight attached to the servomotor crank. The valve shall be suitable for operation under a operating pressure of .....kg/sq.cm and shall be capable of closing against full flow of water and tested at shop for pressure at 1.5 times the rated pressure for 30 minutes. The BF valve offered shall be drop tight and the same shall be proved during the testing. It shall be suitable for connecting to inlet pipe of spiral casing.

The oil pressure required for operation of the butterfly valve may be from governor oil pressure system of individual units or it may have independent power pack. It is envisaged to have remote control for the operation of the BF valve.

Provision shall be made for draining the penstocks. Required piping, valves, pressure gauges etc., shall be included in the scope of supply. .

## **10.3 Body**

Body of the valve shall be in two halves jointed together by flanges and shall be fabricated from steel plates. It shall be heavily ribbed to provide sufficient strength. The body shall be provided with bronze bushings, with grooves for grease lubrication at both ends. The bearings shall be provided with necessary cup seals to prevent inflow of sand or other foreign matter on bushes and leakage of water. The bearings shall be lubricated with grease. The body shall be provided with welded, accurately machined stainless steel seating ring, and supporting foundation feet, foundation plate and anchor bolts. Provision shall be made in supporting feet to allow longitudinal valve movement due to hydraulic forces.

## **10.4 Door/Disc With Sealing Device**

Lattice flow through type disc with integral trunnions shall be of cast steel or fabricated. The trunnions shall have stainless steel sleeves / deposit welded at the portion passing through bearing housing. A peripheral fibre reinforced rubber seal shall be provided on the disc to seal leakages. The rubber seal shall be firmly held in position to the disc by removable steel rings with stainless steel fasteners.

## **10.5 Servomotor**

One swinging type servomotor shall be provided for operating the valve. The cylinder of the servomotor shall be fabricated from steel plates. Piston and piston rings shall be made of cast iron and piston rod of stainless steel. The base plates of the servomotor shall be rigidly anchored into the main foundation.

## **10.6 Bypass Valve**

Oil pressure motor operated bypass valve of adequate size shall be provided for balancing the pressure across the butterfly valve. Two limit switches shall be provided for signaling its open / close position. Metal sealing shall be provided to obtain leak proof seal when the valve is closed. Bypass valve shall be connected to the inlet pipe and downstream

pipe through a steel pipe of suitable length and bore. On the inlet side of bypass valve one hand operated gates / side valve shall be provided.

## **10.7 Other Components**

There are some components which are part of turbine/penstock and are also described in the following paragraphs:

### **10.7.1 Air Valve**

A double acting air valve of suitable bore shall be provided on the downstream of butterfly valve to facilitate supply or release of adequate quantity of air during emptying or filling the spiral casing. The details of valve offered such as vacuum pressure at which the valve operate, the location of its mounting, size of orifice provided with details / calculations etc., shall be furnished.

### **10.7.2 Inlet pipe**

Inlet pipe shall be fabricated from steel plates. One end of the inlet pipe shall be welded with penstock and the other end shall have flange to be bolted to the valve body. The inlet pipe shall have flanged tapings for bye pass valve and cooling system.

### **10.7.3 Dismantling joint**

The dismantling joint shall be of a single fabricated construction provided on downstream side of valve. One end shall be flange connected with valve and other side shall be bolted or welded with spiral case inlet pipe. It shall be used for erection and dismantling of valve. It shall not be designed to take any expansion due to thermal or water hammer effect of penstock. Dismantling joint shall be capable of transferring axial load on spiral casing due to sudden closure of guide apparatus to thrust collar at inlet pipe of spiral case. There shall not be any leakage. The necessary seals etc., shall be provided.

## **10.8 Control Equipment**

One set of control equipment shall be supplied for closing / opening of the butterfly valve. For operating the main servomotor for valve, one main slide valve piloted by a solenoid operated valve shall be provided. For operating bypass valve another solenoid valve shall be provided. For small hydro power stations manual/motorized bye pass valve may serve the purpose. Pressure gauge with electrical contact and suitable number of limit switches shall be provided for remote operation and status monitoring. It shall be possible to operate the BFV remotely from control room.

## **10.9 Locking**

Provision shall be made to lock the disc of the BF valve in its fully closed condition. It shall have a hydraulically actuated/ manual locking valve.

## **10.10 Operation of Butterfly Valve**

Automatic operation of the inlet valve shall be possible from unit control board. Closing of the valve under normal operating condition takes place in practically stand still

water i.e., when turbine gate apparatus is fully closed. In this case valve operation takes place as part of automatic sequence of turbine start / stop or manually from control panel.

Closing of the valve under emergency conditions takes place in case of over speeding of the turbine, very low pressure in oil pressure system or through emergency push button.

The closing of BFV shall be through counter weight only. For opening the inlet valve, bypass valve is opened first, water pressure upstream and downstream of the inlet valve is equalized and the signal is given for opening the BFV.

### 10.11 Technical Details

a.	Material of valve body	Cast steel/Fabricated
b.	Material of valve Disc	IS : 2062 Grad.B
c.	Pressure ratings	
	i. Nominal Working pressure of valve	----- kg/Sq.cm
	ii. Test pressure of valve	----- kg/Sq.cm
d.	Factory of safety	2 for yield point stress under testing conditions.
e.	Time of closing	---- seconds
f.	Time of opening	----seconds
g.	Description of control for opening & closing	Opening of servomotor by oil pressure closing by counter weight
h.	Description of the sealing arrangement	Reinforced solid rubber seals held in position by steel ring fixed by Stainless steel studs and nuts.
i.	Material of sealing arrangement	Reinforced solid rubber seal
j.	Operating oil pressure of the control circuit (servomotor)	To be specified by the bidder

### 10.12 Tests

i) SHOP TESTS

The pressure testing of the valve shall be carried out and witnessed by the purchaser. Test certificates shall be furnished for the test conducted to the purchaser for approval.

ii) FIELD TESTS

The opening and closing of the valve under severe conditions of operation and other tests as per the relevant standards.

### 10.13 Drawings

A set of assembly drawing shall be furnished with the bid document.

### 10.14 Technical Specification of Spherical Valve

#### 10.14.1 Scope

This section of the specifications covers the complete engineering, design, manufacture, testing at factory before dispatch, supply, delivery to project sites, supervision

of onsite erection, testing, commissioning and putting into commercial use of turbine inlet spherical valve complete with its associated control equipment, accessories, piping etc. and also supply and delivery at site of spares, tools and erection equipment as mentioned hereafter.

### 10.14.2 Design requirements

#### Basic Design Data

- i) Number of spherical valves :
- ii) Purpose : Turbine Guard valve
- iii) Nominal diameter of inlet valve : Diameter should be matching with turbine inlet diameter
- iv) Design head : .....m.w.c (.....MPa)
- v) Test pressure : .....m.w.c. (.....MPa)
- vi) Rated discharge : ..... m<sup>3</sup>/sec.
- vii) Breakdown discharge : ..... m<sup>3</sup>/sec.
- viii) Operation : Opening: By oil pressure  
: Closing : By counter weight
- ix) Closing time of spherical valve :
  - at still water : <....sec.
  - at rated discharge : <.... sec
  - under breakdown discharge: <....sec
- x) Opening time : <.... sec
- xi) Spherical valve shall have preferably its own pressure oil system or hydraulic power pack .
- xii) The spherical valve and its control system shall be suitable for frequent opening and closing.
- xiii) The head loss in spherical valve for rated discharge of----- m<sup>3</sup>/sec shall be guaranteed.

### 10.14.3 Design specifications and performance

The spherical valve shall be free from vibration or other abnormality under steady-state operating conditions and under any possible transient conditions and shall have sufficient strength and rigidity against maximum transient water pressure conforming to IS:7326-2008.

#### 10.14.3.1 Required service conditions

It shall always be possible to close the spherical valve safely, without vibrations or pressure surges, particularly,

- (i) In normal service conditions with turbine guide vane/ nozzles closed. i.e. without significant water flow
- (ii) In case of emergency with turbine guide vane/ nozzles fully open i.e., with rated discharge and with full pressure on one side of the closing element near the end of closure.
- (iii) In case of an accidental rupture of the pipe between the spherical valve and the turbine

inlet (i.e. with the breakdown discharge and the whole pressure on one side already at the beginning of closure.)

#### **10.14.3.2 Guarantees**

Guarantees for spherical valves must be given by the Bidders for:

- (i) Low level of vibration and noise during closing .
- (ii) Strong construction and adequate design of housing.
- (iii) Proven design.
- (iv) High level of water sealing.
- (v) Minimum losses in the opened position.

#### **10.14.3.3 Control**

Operation of spherical valve shall be hydraulically by means of its own oil pressure unit or hydraulic power pack. Following modes of control shall be provided.

- Manual local from the respective control cabinet near spherical valve location.
- Manual remote from the unit control board located in power Station control room.
- As part of automatic control sequence of turbine generating unit. The spherical valve shall have automatic interlock devices.

#### **10.14.3.4 Discharge shutdown performance**

Inlet valve shall be capable of shutting down rated discharge of turbine at all heads safely and reliably under unbalanced conditions. Also spherical valve shall be capable of closing during emergency conditions, safely and completely against full unbalanced flow occurring as a result of breakdown of Nozzle/Deflector assembly in Pelton turbine. Opening under balanced conditions or otherwise shall be decided in consultation with turbine manufacturer so as to achieve stipulated time for synchronizing of unit from stand still.

#### **10.14.3.5 Amount of water leakage**

Amount of water leakage past downstream side seal shall be less than 0.5 litre per minute at the maximum static pressure . Amount of water leakage past from upstream side seal at above mentioned water pressure shall not be more than 0.8 litre per minute.

#### **10.14.4 Construction**

The spherical valve shall be provided with two seals. One “service seal” on down stream side and other “maintenance seal” on the upstream side

##### **10.14.4.1 Valve body**

Valve body shall be made of carbon steel casting or welded steel plates. It shall be suitably divided in maximum two pieces which shall be connected by a flange. Valve body shall be of sufficiently stiff structure to withstand the maximum water pressure during transient conditions of turbine and to cause no detrimental deformation. Valve rotor shall be provided with trunions of forged steel at both ends. Valve trunions shall have sufficient

diameter and shall not cause excessive deflection. Trunion bearing shall be greaseless self lubricating with bronze backing and with Teflon fabric liner. Trunion bearing seals shall be on both ends of each bearing and shall be made of suitable self lubricating material. Bearing shall be capable of safely supporting the weight of the valve rotor and force caused by water pressure and shall be capable of operating valve smoothly.

#### **10.14.4.2 Service seal and maintenance seal**

The sealing system one for normal service on downstream side of the spherical valve and the other on the upstream side for maintenance of the service seal shall be provided. The design and construction of the seals shall be such that a service life of about 50,000 hours is guaranteed i.e. the expected mean time between failure (MTBF) shall be about 50,000 hours. Further the sealing arrangement shall be such that when worn out, the service seals could be replaced without having to dismantle the valve without dewatering of penstock. The complete method and sequence of replacing the service seals shall be furnished in the bid with explanatory write-ups, sketches and drawings. The design and construction of the maintenance seals shall be similar to that of service seal.

#### **10.14.4.3 Valve rotor**

Valve rotor shall be made in spherical shape by carbon steel casting or welded steel plates. The rotor shall have sufficient strength against all operating conditions so that it will not cause any detrimental deformation. Besides, the rotor shall not cause any abnormal vibration during full opened position or during opening and closing operations or fluttering during transport conditions. Arrangement for removal of air trapped in the dome of valve shall be made. No air shall accumulate inside valve body.

#### **10.14.4.4** Following items are part of turbine/penstock

##### **(i) Air valves**

Suitable capacity air admission valve shall be provided on down stream side of valve to protect Inlet piping and shall also act as air exhaust valve. However leakage of water shall not occur during operating conditions.

##### **(ii) Inlet pipe with connecting piece**

A connecting pipe shall be provided between the inlet valve and the Penstock. The connecting pipe shall be made of same material as Penstock (ASTM 517 Gr. for equivalent). The inlet valve and connecting pipe shall be connected by rigid flanges and connecting bolts and nuts and packing shall be supplied. The connecting pipe shall be welded with penstock.

##### **(iii) Penstock Drainage System**

Necessary piping with fittings shall be supplied for draining the penstock into tail race channel.

##### **(iv) Operating Mechanism**

Valve operating mechanism shall comprise of servomotor, operating rods, levers,

interlocks and limit switches, counter weight for closing operation by weight and pressurized water piping necessary for closing . Opening of the valve shall be achieved by oil pressure. Closing of the valve shall be achieved by counter weight /hydraulic system. The Servomotors shall be of balancing type and heavy supporting plates with anchor bars, fastening etc. shall be provided to mount the same on foundation block.

Main parts of the operating mechanism such as servomotor, operating rods, levers, and connecting part with the valve trunnions shall have strength and capacity sufficient for safely and reliably shutting down and opening full flow discharge under all operating conditions of turbine without causing any excessive vibration and other abnormality. Dimensioning of piston shall be so as to transmit all operational forces without deflections. All pivots shall be preferably of self lubricated type. Operating mechanism shall be provided with a locking device capable of manually locking of the main valve. Fasteners which come in contact with water supply shall be made of stainless steel. Limit switches, for open /close, transmitters, contacts etc. for local / remote operation and indication of valves shall be provided.

**(v) Accessories**

Following accessories shall be supplied.

- (i) Position switch.
- (ii) Valve opening / closing indicator.
- (iii) Pressure gauge for inlet to spherical valve with relay.

**10.14.4.5 Oil pressure system for spherical valves**

Spherical valve shall be provided with one independent oil pressure unit to supply oil under pressure to servomotors. For smaller machines where closing of valve is done by counter weight, independent hydraulic power pack may be used without pressure accumulator.

**10.14.4.5.1 Purpose**

Oil pressure unit system/ hydraulic power pack shall be used for opening of the spherical valve. Operation control devices for the valve system shall be independent of the governing system of turbine.

**10.14.4.5.2 System**

A complete oil pressure unit shall be provided for spherical Valve. Each system shall compromise of following: One sump tank located adjacent to each spherical valve and dimensioned for 120% of the combined oil volume in the servomotors in fully open positions, oil piping valves and pumps. The tank shall be provided with a filling opening (with strainer and cover) breather, breather opening, sight oil gauge with cocks and drain with cock and one manhole for inspection. Dial type oil level gauge and oil level relays for oil level low / high warnings. Two screw type silent running and self priming oil pumping unit One each for normal and stand by, each with suction strainer and capable of continuous operation. The pumps shall be vertical rotary type coupled directly with their drip proof alternating current electric induction motors. Both pumping units shall be identical and equipped with complete control system permitting the selection of either unit acting as stand-by and starting automatically when other pumping unit fails.

Each pressure oil pump shall be a vertical shaft rotary pump. The oil flow rate per pump at the maximum delivery pressure will be sufficient for operating the spherical valve from the fully closed state to the fully opened state without supply of pressure oil from the pressure tank. The normal operating oil pressure shall be suitable to meet the stipulated operational requirements. Each of the normal and stand by pumps shall be provided with the following accessories.

- 1 set Safety valve.
- 1 set Non-return valve.
- 2 set Strainer.

One small pressure oil accumulator in parallel arrangement between the oil pumps and servomotor and located near the valve. This accumulator shall act as buffer and pressure oil holding means to prevent the oil pump from frequent starting. One hand operated double acting oil pump mounted in the sump tank shall be provided.

Control valves for spherical valve drives and seal applications shall be as follows:

- (a) All valves: such as safety valves, non-return valves etc.
- (b) All oil piping and isolating valve within the oil pump tank and between the oil pumping set and servomotors.
- (c) Control cabinet containing following instruments and switches
  - (i). Two pressure gauges with contacts for indication of upstream and downstream water pressure of valve with recording facilities.
  - (ii). One pressure gauge for indication of oil pressure with contacts.
  - (iii). Selector switches for local / remote and auto / manual control of pumps.
  - (iv). Control switches for pumps.
  - (v). One pump selector switch for main and stand –by.
  - (vi). Three push selector switch for opening, stop and closing of spherical valve.
  - (vii). One selector switch for local / remote and auto / manual control of spherical valve.
  - (viii). One switch with ‘ON’ and ‘OFF’ position for testing of oil pumping units.
  - (ix). One electric heating element.
  - (x). All necessary relays, fuses, signal lamps, terminal blocks and other equipment for a complete and safe local and remote control of the spherical valve.

The cabinet shall be of self standing sheet metal type, moisture, vapour and dust proof, with lockable front door. All wiring shall be in the most efficient manner from point to point. There shall no jointing or teeing of wires between terminals. All control cabling between individual devices, instruments, switches etc. up to local control cabinet of spherical valve shall be provided.

Control of pumps shall also be possible from the unit control board in addition to local control and shall operate in conjunction with turbine controls. Operation of the pressure oil pump shall be controlled by pressure switches when the normal oil pump fails, the stand by pump shall start automatically. Change over between the normal operation and stand-by pump will be carried out through the change over switch provided on the control cabinet.

Provisions in the control scheme for shutting off the unit be provided in case of valve closure.

Besides, starting and stopping shall be carried out not only automatically and remotely but also manually from control cabinet .All position indicators annunciators and control shall be suitable for local and remote operations. First filling plus 25% extra quantity for each unit of pressure system oil, required for each Sp. valve and its pressure oil system shall be supplied by the supplier. Supplier shall suggest the oil equivalent available in India for future maintenance and operation of the plant.

#### **10.14.4.6 Accessories**

Following shall be supplied but shall not be limited to

- (i). All necessary sole plates, foundation bolts, anchors etc. for Sp. valve and servomotor.
- (ii). All platforms, ladders, stairs, handrails, plate coverings, hooks, pulley blocks etc. necessary for obtaining easy and safe access to parts and item which are fitted with equipment.
- (iii). The name plate for each equipment showing manufacturers name, serial number, year of manufacture, type, rating, capacity etc. for valve assembly and servomotor shall be provided.
- (iv). All necessary washers, bolts, nuts etc. of high quality steel.
- (v). All necessary turn buckles and pipe jacks needed for erection, operation and maintenance.

#### **10.14.4.7 Tools and Erection Requirement**

One (1) complete set of ordinary and special spanners, wrenches, special tools, slings, shackles, ropes etc. for the proper erection and maintenance of the valve shall be supplied. One complete set of smaller and standard tools and equipment shall be furnished with a sheet metal lockable toolbox, fitted internally so that the tools may be stored in a proper manner.

#### **10.14.8 Hydraulic Pressure Test at Site**

If the transport limitations permit, the spherical valve shall be dispatched in one piece duly assembled in workshop. In case, it is not possible to transport assemble valve to project site, it shall be pressure tested at site.

To carry out the pressure testing at site, the supplier shall provide one set of bulkheads for spherical valve together with all necessary pickings and jointly material and test equipment.

#### **10.14.9 Drawings**

A set of assembly drawing shall be furnished with the bid document.

#### **10.14.10 Inspection and Tests**

- (i) Inspection and tests at works shall be carried out by the supplier in respect of the spherical valve as per the list given below:
  - (a) Dimensional check of components.

- (b) Pressure Test of body and complete valve
  - (c) Leakage test of seals.
  - (d) Operational check for smooth operation
- (ii) Test at site

The opening and closing of the valve under severe conditions of operation and other tests as per the relevant standards.

## 11.0 TECHNICAL SCHEDULES

The Bidder shall complete this schedule of guaranteed technical particulars & performances

### I. GUARANTEED TECHNICAL PARTICULARS FOR MAIN INLET VALVE

S. No.	PARTICULARS	
<b>1.</b>	<b>Main Inlet Valve</b>	
a.	Make of Valve	
b.	Diameter of valve	
c.	Type of Valve	
d.	Nominal working pressure	
e.	Design pressure	
f.	Test Pressure	
g.	Time of opening of valve	
h.	Time of closing of valve	
i.	Pressure drop across Valve	
<b>2.</b>	<b>Servomotor rated/Maximum flow</b>	
a.	No. of Servomotors	
b.	Diameter of servomotor	
c.	Stroke of servomotor	
d.	Max. pressure of oil pressure system	
e.	Material	
	i) Cylinder	
	ii) Piston	
<b>3.</b>	<b>By Pass Valve</b>	
a.	Type of bypass valve	
b.	No. of bypass valve	
c.	Diameter of bypass valve	
<b>4.</b>	<b>Air Valve</b>	
a.	No. of air valves	
b.	Diameter of air valve	
<b>5.</b>	<b>Heaviest Package for Shipment</b>	
a.	Name	
b.	Weight	
c.	Dimensions (L x B x H) (m x m x m)	
<b>6.</b>	<b>Largest package for shipment</b>	

S. No.	PARTICULARS	
a.	Name	
b.	Weight	
c.	Dimensions (L x B x H) (m x m x m)	
<b>7.</b>	<b>Heaviest assembly to be lifted by Power House Crane</b>	
a.	Name	
b.	Weight	
c.	Dimensions (L x B x H) (m x m x m)	
<b>8.</b>	<b>Details of Dismantling Joint</b>	
a.	Length	
b.	Weight	
c.	Material	
d.	Diameter	

## II. PERFORMANCE GUARANTEES OF TURBINE AND GENERATOR

### S. No. ITEM

#### a. Turbines

##### i. Guaranteed Output

- (a) At rated head
- (b) At maximum head
- (c) At minimum head

##### ii. Guaranteed Efficiency at rated head for the following output.

- (a) 110%
- (b) 100%
- (c) 80%
- (d) 60%

#### b. Generator

##### i. Guaranteed outputs and temperature rises values Rated output and maximum guaranteed temperature rise at rated output and rated power factor kW \_\_\_\_\_

(a) Rated power factor \_\_\_\_\_ pf \_\_\_\_\_

(b) Maximum guaranteed temperature rise \_\_\_\_\_ °C \_\_\_\_\_  
(Ambient air at 40°C and water temperature at 25°C)

(c) Output at Class F temperature rise \_\_\_\_\_ kW \_\_\_\_\_

##### ii. Guaranteed Efficiencies

Rated Load	110%	%
Rated Load	100%	%
Rated Load	80%	%
Rated Load	60%	%

### III. GUARANTEED TECHNICAL PARTICULARS OF MAIN GENERATING EQUIPMENT

#### (A) TURBINE & GOVERNING SYSTEM

S. No.	Description	Values (to be filled in by the Bidder)
1.	Name of manufacturer	
2.	Type of turbine	
3. (a)	Guaranteed rated turbine output at i. Rated head of m ii. Max. head of m	
3 (b)	Guaranteed turbine output at i. Max. head of m ii. Min. head of m	
4.	i) Guaranteed turbine efficiency at rated head at: <ul style="list-style-type: none"> <li>• 110% of rated output</li> <li>• 100% of rated output</li> <li>• 80% of rated output</li> <li>• 60% of rated output</li> </ul> ii) Guaranteed turbine efficiency at max. head at : <ul style="list-style-type: none"> <li>• 110% of rated output</li> <li>• 100% of rated output</li> <li>• 80% of rated output</li> <li>• 60% of rated output</li> </ul> iii) Guaranteed turbine efficiency at min. head at : <ul style="list-style-type: none"> <li>• 110% of rated output</li> <li>• 100% of rated output</li> <li>• 80% of rated output</li> <li>• 60% of rated output</li> </ul>	
5.	Turbine discharge at rated design head at : <ul style="list-style-type: none"> <li>• 110% of rated output</li> <li>• 100% of rated output</li> <li>• 80% of rated output</li> <li>• 60% of rated output</li> </ul> Turbine discharge at max. head at : <ul style="list-style-type: none"> <li>• 110% of rated output</li> <li>• 100% of rated output</li> <li>• 80% of rated output</li> <li>• 60% of rated output</li> </ul> Turbine discharge at min. head at : <ul style="list-style-type: none"> <li>• 110% of rated output</li> <li>• 100% of rated output</li> <li>• 80% of rated output</li> <li>• 60% of rated output</li> </ul>	
6.	Speed	

S. No.	Description	Values (to be filled in by the Bidder)
	a) Specific speed in M.K.S units b) Rated speed in rpm c) Max. runaway speed in rpm i. off-cam / on-cam d) Direction of rotation when viewed from generator end	
7	Best efficiency and corresponding output & head	
8.	Momentary rise in speed on sudden full load rejection (% of rated speed)	
9.	Momentary rise in pressure in penstock on sudden full load rejection (% of rated head)	
10.	Time of gate closing for regulation in item-7 above (Full load gate opening to no load gate opening)	
11.	Optimum Time of gate opening from no load to full rated load gate opening	
12.	Time of opening & closing of runner blades (for full stroke )	
13.	Flywheel effect of the generating unit Generator rotating parts                      kg m <sup>2</sup> Turbine runner and shaft                      kg m <sup>2</sup> Fly wheel    kg m <sup>2</sup>	
14.	i) Max. Axial hydraulic thrust (downstream) at full load at max. head ii) Max. negative hydraulic thrust (upstream) and condition of occurrence	
15.	i) Calculated load on upstream guide/thrust bearing a) Dry condition b) Watered condition ii) Calculated load on downstream guide bearing a) Dry condition b) Watered condition	
16	Guaranteed Max. Vibrations at rated load: a) at turbine shaft by non-contact probe near guide bearing b) at bearing housing c) at draft tube manhole	
17	Guaranteed max. noise level a) at turbine floor b) one meter away from throat ring	
18.	Factor of safety a) Guaranteed minimum factor of safety under worst condition based on yield point of the material. (Unit stress should not exceed 2/3 <sup>rd</sup> of yield point stresses.) b) Name and location of the parts having the factor of safety in (a) above for rated load and for overload.	

S. No.	Description	Values (to be filled in by the Bidder)
19.	Stay Ring a) Inside diameter of stay ring b) Outside dia. of stay ring c) Max. design pressure d) No. of stay vanes e) Material of stay ring cones f) Plate thickness of stay ring g) Total weight of stay ring h) Number of transportable sections	
20.	Runner (Kaplan) a) Blades Tip Diameter b) Hub outer diameter c) No. of blades d) Servomotor diameter e) Servomotor stroke f) Regulating capacity of servomotor in kg.m. g) Blade angles in full closed and opened position h) Max.& Min. operating Pressure required i) Material of Hub j) Material of runner blades (13Cr.4Ni. stainless steel) k) Material of Blade trunion l) Material of Servo-motor body and piston m) Weight of assembled runner with blades	
21.	Throat Ring ii. Internal diameter iii. Min. guaranteed Plate thickness iv. Material of shell v. Weight of throat ring	
22.	Turbine Shaft a) Material and composition b) Outside/inside diameter c) Overall Length d) Diameter of runner end flange , no & dia. of coupling bolts e) Diameter of generator end flange, no & dia. of coupling bolts f) Weight of shaft	
23.	Guide Bearing : a) Bearing journal diameter b) Method of Lubrication c) Maximum oil temp. with cooling water supply d) Maximum oil temp. without cooling water e) Type of coolers – built-in or external f) Requirement of cooling water g) Material of shell and babit	

S. No.	Description	Values (to be filled in by the Bidder)
	h) Type/grade of oil & its viscosity at 40 <sup>0</sup> C	
24.	Shaft Sealing a) Type b) Diameter of sleeve for sealing c) Requirement of cooling water l/sec d) Quality of cooling water (impurity in ppm) e) Type of maintenance seal f) Pressure of air required for air seal	
25.	Wicket Gates Assembly (Francis & Kaplan Turbines) a. No of wicket gates b. Height of wicket gate c. Dia of upper/outer journal d. Dia. of lower/inner journal e. Feather length of wicket gate f. PCD of wicket gates on outer cone g. Max. end clearances of wicket gates h. Material / make of self lubricating bushes i. Material of wicket gates j. No. of servomotors k. Diameter of Servomotors l. Stoke of servomotor m. Min. required pressure to operate wicket gates at max. head n. Material of servomotor cylinder & piston o. Max. oil leakage past piston with Turbine oil IOC46 at 20 deg C. p. Material of distributing outer/inner cone	
26.	Draft Tube (a) Total length of draft tube (b) Length of steel liner (c) thickness of steel liner (d) Cross section at outlet (e) Velocity under full load at Draft tube exit Draft tube liner end (f) weight of draft tube liner	
27.	Cavitation factors a) Elevation of recommended center line of unit b) Critical sigma c) Recommended plant sigma d) Max. pressure pulsations in draft tube	
	<b>Governing System</b>	
28.	<b>Oil Pumping Unit</b> a) Effective volume of sump tank b) Dimensions of sump tank c) Total volume of oil in the governing system	

S. No.	Description	Values (to be filled in by the Bidder)
	d) Number of pumps & their type & make e) Capacity of each pump f) Speed of rotation of pumps g) Duty of operation ( Cont./Intermittent) h) Motor rating i) Class of insulation j) Type & make of float switches	
29.	Oil Pressure Vessel a) Normal volume of pressure vessel b) Dimensions of vessel (D x t x H) c) Volume of oil in vessel d) Normal working pressure e) Min. pressure for safe operation f) No. of complete operations w/o pumps running g) Oil qty. left in vessel after min. pressure at (e) h) Material i) Code to be followed for design, mfg & testing j) No., type & make of pressure relays k) No. type & make of float switches l) Grade of oil recommended m) Weight	
30.	Oil Leakage Unit a) Effective volume of leakage oil tank b) Dimensions of tank c) Number of pumps & their type & make d) Capacity of each pump e) Speed of rotation of pumps f) Motor rating g) Class of insulation h) Type & make of float switches	
31.	Electro Hydraulic Governor i) Electronic Regulator Cubicle : Make of governor regulator Type of regulator (digital/analogue) Type of processor & function language used Voltages used Type of speed or level responsive element Range of adjustment of permanent speed droop Range of adjustment of temporary speed droop – bt & Td ( on line / off line ) Range of adjustment of speed setting Range of dead band adjustment No of input/output channels (digital/analogue ) No of speed relay outputs ii) Governor Actuator Cubicle	

S. No.	Description	Values (to be filled in by the Bidder)
	Type of actuator used Operating oil pressure Min. oil pressure necessary for operation Distributing valve dia. (gate & runner control) Type of combinatory relation (gate Vs runner opening) mechanism – mechanical/electronic Type of feedback/restoring mechanism used Adjustment range in governor opening and closing time. Guaranteed sensitivity Type of over speed protection device	
32.	Largest Package for shipment a) Name b) Weight c) Dimension (LxWxH)	
33.	Heaviest Package for shipment: Name Weight Dimension (LxWxH)	
34.	Heaviest assembly to be lifted by P.H. EOT Crane during erection/maintenance : Name Weight Dimension (LxWxH)	

**(B) GENERATOR, EXCITATION SYSTEM AND TERMINAL EQUIPMENT**

The following technical data, guaranteed performance and other particulars shall be furnished by the Bidder in his bid.

Item No.	Generator	
1.	Name of manufacture and place of manufacture,	
2.	Type and class	
3.	i. Normal rated voltage between phases ii. Minimum terminal voltage under operating conditions with unloaded system. iii. Terminal voltages at which the rated output at 0.9 lagging power factor must be delivered.	

Item No.	Generator	
4.	Guaranteed Maximum continuous output at 30 centigrade temperature of cooling water for Generator surface air coolers and 110 <sup>0</sup> centigrade winding temperature under following terminal conditions. Rated voltage _____ kV rated lagging P.F. Maximum voltage _____ kV unity P.F. Rated voltage _____ kV rated leading P.F.	_____ KVA _____ KVA _____ KVA
	Minimum voltage _____ kV Zero leading power factor and a minimum excitation of 12% of excitation for (I) above	_____ KVA
5.	Guaranteed maximum temperature rise for maximum Continuous output guaranteed in item 4 at 30 <sup>0</sup> Centigrade maximum temperature of cooling water for Generator surface air coolers and ambient air temperature. (i). Stator winding by embedded resistance type temperature detectors. (ii). Rotor winding by resistance method (iii). Cores and other mechanical part as measured by thermometers.	
6.	Maximum line charging capacity of the Generator, neglecting heating without the Generator becoming completely self excited or unstable when operating at normal rated voltage and frequency and without field, when connected to a transmission circuit or circuits, open circuited at the receiving end.	_____ KVA.
7.	Type and class of insulation of Stator winding Field coils (rotor)	
8.	Guaranteed losses, in kilowatts at rated kVA, at rated power factor lagging. Field I <sup>2</sup> R loss. Exciter and exciter rheostat losses . Friction and windage loss Core loss.	
	Armature I <sup>2</sup> R loss . Stray load loss. Total losses	
9.	Guaranteed overall efficiency of the Generator, along with Exciter, etc at rated terminal voltage and rated kVA and 110 <sup>0</sup> C winding temperature at rated power factor lagging. 60 percent rated kVA not less than percent 105 percent rated kVA not less than percent	

Item No.	Generator	
	110 percent rated kVA not less than percent.	
10.	Inherent regulation in percent of rated voltage i.e rise in terminal voltage on taking off. 25 percent rated output 50 percent rated output 75 percent rated output 100 percent rated output	
11.	Reactance and Resistances,(%) Direct and quadrature-axis synchronous reactance. Direct – axis transient reactance unsaturated/ saturated. Direct and quadrature axis sub transient reactance unsaturated Negative sequence reactance sub transient unsaturated Zero sequence reactance	
12.	Short circuit ratio	_____
13.	Wave form Expected wave form curve drawing to be provided Maximum deviation factor of wave form fundamental (in percent of peak value of the fundamental) when measured from oscillograms taken of the wave form of the voltage of each phase of armature winding when the Generator is operating at rated voltage and open circuit. No load balanced telephone interference factor. No load residual telephone interference factor.	
14.	Synchronizing power per electrical radian (at rated terminal voltage and rated output at 50 cycles 0.9 lagging power factor).	_____KW
15.	Fly wheel effect ( $WR^2$ ) of the rotating parts (Generator and Exciter)	_____kg m <sup>2</sup>
16.	Maximum runaway speed at which all parts are guaranteed to withstand mechanical stresses safely.	_____r.p.m.
17.	No. and type of embedded temperature detectors.	_____
18.	Voltage Regulators Name of manufacturer and place of manufacture. Type, class and rating. Guaranteed sensitivity for quick response element.	_____ _____

Item No.	Generator	
	Minimum time taken to response at given sensitivity at ½ % variation in Generator terminal voltage. Range of voltage level setting	_____Secs. .....% to.....%
	Range of adjustment of line drop compensation at full load. Range of adjustment of line drop constants Is parallel running compensation provided.	.... % to.....%
19.	Overall diameter of generator.	_____mm
20	Diameter of stator frame	_____mm
21	Diameter of Rotor	_____mm
22	Diameter of Shaft.	_____mm
23	Generator surface air coolers No. and type of coolers. Total air cooling surface area per Generator Water pressure required for cooling. No. of spare coolers, if any. Cooling water at 30 <sup>0</sup> C required, per generator	_____m <sup>2</sup> _____kg/cm <sup>2</sup> _____LPS
24.	Stator i. No. of sections of generator stator ii. Type of material and insulation of stator punching. iii. Type of stator frame construction. iv. Type of slot insulation. v. Type of stator coil insulation. vi. Height of stator core. vii. Inside diameter of stator. viii. Outside diameter of Stator. ix. Weight of assembled stator with coils without coolers and housing	_____ _____ _____ _____mm _____mm _____kg
25	Generator Housing i. Height from generator floor level. ii. Outer diameter. iii. Air volume within the generator air enclosure	_____mm _____mm _____m <sup>3</sup>
26.	Rotor . i. Material and construction of rotor ii. Overall diameter and weight of rotor run	_____ _____mm
27.	Core. i. Material and construction of rotor core ii. Method of fixing field poles to rotor rim iii. Method of fixing spider to rotor shaft. iv. Weight of rotor with field coils. v. Material and construction of field coils. vi. Construction of amortissour winding.	_____ _____ _____kg _____
28.	Generator main shaft.	

Item No.	Generator	
	i. Material ii. Diameter at thrust bearing end. iii. Overall length. iv. Diameter of axial hole , if hollow v. Weight of shaft.	_____ _____ mm _____ mm _____ kg
29.	Generator bearing bracket. i. Materiel and construction ii. No. of arms. iii. Weight. (kg)	
30.	Thrust bearing. i. Make and type. ii. Total load on thrust bearing including unbalanced hydraulic thrust (kg) iii. Diameter of thrust runner.(mm)	
	Material and construction of runner. Material and construction of thrust shoes No. of thrust shoes per thrust bearing	
	No. of guide shoes per thrust bearing if provided.	
	Effective bearing surface of complete thrust bearing(cm <sup>2</sup> ) Location of thrust bearing Capacity of lubricating oil reservoir(Liters) Pressure of water required for cooling (kg/cm <sup>2</sup> ) Cooling water at 30 <sup>0</sup> C required per Generator( LPS) Means of checking loading on each thrust shoe.	
31.	Guide bearings Make and type. Effective bearing surface(cm <sup>2</sup> ) Location Material and construction Pressure of water required for cooling(kg/ cm <sup>2</sup> ) Cooling water at 30 <sup>0</sup> C required per Generator (LPS)	
32.	Lubricating system. <ul style="list-style-type: none"> <li>• Recommended viscosity of lubricating oil for thrust bearing in Saybolt-seconds, at 40<sup>0</sup>C.</li> <li>• –do—for guide bearing</li> <li>• Type No. &amp; H.P. of oil pumps for thrust bearing lubricating system if forced lubricated</li> <li>• –do- for guide bearing lubricating system if forced lubricated</li> </ul>	
33.	Generator Brakes Air pressure for brakes. Speed at which brakes are applied	_____ kg/cm <sup>2</sup> _____ rpm
34.	Excitation Equipment i.)Name of manufacturer ii.)Type iii.)Accuracy of voltage regulation	



Item No.	Generator	
	<ul style="list-style-type: none"> <li>• Times rated current</li> <li>• Times in seconds</li> </ul>	
	<p>Knee point voltage _____</p> <p>Basic insulation level _____</p> <p>Winding temperature rise _____</p> <p>Secondary winding resistance _____</p> <p>iii) Potential Transformers _____</p> <p style="padding-left: 20px;">Type _____</p> <p style="padding-left: 20px;">Name of manufacturer _____</p> <p style="padding-left: 20px;">Standard to which it conforms _____ Volts</p> <p style="padding-left: 20px;">Manufactures type designation _____ Volts</p> <p style="padding-left: 20px;">Rated primary voltage _____</p> <p style="padding-left: 20px;">Rated secondary voltage _____</p> <p style="padding-left: 20px;">Rated burden _____</p> <p style="padding-left: 20px;">Accuracy class _____ KV (rms)</p> <p style="padding-left: 20px;">Temperature rise at 1.1 times rated voltage with rated burden and frequency _____</p> <p style="padding-left: 20px;">One minute power frequency withstand test voltage on primary _____</p> <p>iv). Neutral grounding equipment.</p> <p>a. Distribution Transformer and secondary Resistor</p> <p style="padding-left: 20px;">Type _____</p> <p style="padding-left: 20px;">Name of manufacturer _____</p> <p style="padding-left: 20px;">Voltage ratio _____</p> <p style="padding-left: 20px;">Continuous rating _____</p> <p style="padding-left: 20px;">One minute rating _____</p> <p style="padding-left: 20px;">Secondary load resistance (ohms) _____</p> <p style="padding-left: 20px;">Current rating of resistor _____</p> <p style="padding-left: 20px;">Duty cycle of resistor and cooling medium _____</p> <p style="padding-left: 20px;">Overall dimensions and weight _____</p> <p>b. Neutral Isolating Switch</p> <p style="padding-left: 20px;">Type _____</p> <p style="padding-left: 20px;">Name of manufacturer _____</p> <p style="padding-left: 20px;">Voltage rating, frequency _____</p>	
	<p>Normal current _____</p> <p>Short time rating _____</p> <p>1.2/50 Micro Second impulse level _____</p> <p>1 minute power frequency dry withstand voltage _____</p> <p>Dimensions and weight _____</p>	
37.	<p>c. Generator Transformer cables</p> <p style="padding-left: 20px;">Name of Manufacturer _____</p> <p style="padding-left: 20px;">Type of cable _____</p> <p style="padding-left: 20px;">Size and rating. _____</p> <p style="padding-left: 20px;">Short circuit stresses. _____</p> <p style="padding-left: 20px;">Maximum temperature of cables when delivering rated output continuously at 45<sup>0</sup>C ambient air temperature. _____</p>	

<b>Item No.</b>	<b>Generator</b>	
38.	d. CO <sub>2</sub> Fire Extinguishing System Make No. of CO <sub>2</sub> cylinders for initial discharge protection No. of CO <sub>2</sub> cylinders for delayed discharge bank No. of cylinders in reserve cylinder battery No. of fixed temperature electric thermostat	 <hr/> <hr/> <hr/> <hr/>