BHEL – INTERNATIONAL OPERATIONS DIVISION, NEW DELHI

Ref: X/10/246
Dtd: 21st July'11

Subject: Invitation for Expression of Interest for Business Sharing for Hydro Turbines

BHEL is a premier Undertaking of Government of India, with an annual turnover of over USD 10 billion (approx.), manufacturing over 180 products in areas such as Power Generation, Transmission, Industry, Transportation, Telecommunication, Renewable Energy and Defence. BHEL has dual advantage of being both, a manufacturing & engineering company as well as EPC contractor for execution of projects from concept to commissioning. BHEL's expertise and excellence are backed by 50 years of rich experience and today BHEL has established footprints in over 70 countries across the world with total capacity of projects contracted in India and overseas having crossed 1,00,000 MW. In the field of hydro power projects, BHEL has designed, manufactured, supplied and commissioned in India and abroad more than 410 machines of various sizes and ratings including 165 MW Dehar Project in Himachal Pradesh, India; 6 x 170 MW Tala Project in Bhutan and 4 x 200 MW Koldam Project also in Himachal Pradesh, India. BHEL has also supplied various assemblies / components for 6 x 250 MW Nathpa Jhakri project in India in association with foreign partners.

To address a 6 x 100 MW hydro sector opportunity, BHEL is looking for suitable partner for turbines who can associate with us on business sharing basis for participation in the opportunity with Vertical Francis Turbines of 150 rpm and above with technical parameters as attached. The following is proposed to be kept in the scope of prospective partner:

1. Hydraulic Design
2. Model Design & Testing
3. Field Testing and Guarantee fulfillment
4. Supply of relevant information for manufacturing items based on mutually agreed Division of Work (DOW).
5. Balance of Work such as detailed design, manufacturing and supply of turbine equipment will be done by BHEL for items in BHEL scope.

In view of details and background given above, EOI for business sharing along with vendor credentials and detailed proposal in sealed cover is invited so as to reach the undersigned not later than 21 days from the date of this invitation for EOI. The sealed cover should be super scribed with "EOI for Business Sharing for Hydro Turbines".

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TECHNICAL PARAMETERS (TYPICAL) – HYDRO TURBINES

MAIN TECHNICAL PARAMETERS, GUARANTEES AND MODEL TEST

1.1 Type & Rating

a) Hydraulic Data

Full Reservoir Level FRL	1030m
Minimum Draw Down Level MDDL	1028m
Average tail water level-Max TWL-1/3(Max TWL-Min TWL)	960m
Average Head loss in WCS	9.5m
Maximum gross head, one in unit operation	70.00m
Minimum gross head, all units in operation	68.00m
Maximum net head, one in unit operation m	60.5m
Minimum net head, all units in operation m	58.5m
Rated & Design Net Head* m	
* (Rated net head =Max. net head-1/3(Max. net head-Min net head)	60m

b) Turbine Basic Data

Rated and Design Net Head	60m
Head Range	58.5 m –70 m
Maximum Net Head with one unit running at FRL	60.5 m
Normal Maximum Net Head with all units running at Maximum Load at FRL	60.5m
Minimum Net Head with all units running at Rated Load at MDDL	59.5 m
Rated Continuous Output Capacity at rated net head of 60m	Not less than 102000 kW
Maximum Continuous Output Capacity	Not less than 112000 kW
Operation Capability under Part Load without any adverse effect	To be guaranteed by the bidder.
Continuous output at design head at best efficiency point	*To be furnished by the bidder along with corresponding efficiency & gate opening*
Maximum Speed Rise on maximum load rejection	55%

Maximum penstock Pressure Rise on load rejection	35%
Rated speed	150RPM
Note: Bidder may examine and quote other speed as per their design practice to achieve optimum machine performance and substantiate with calculations as regards the rated speed adopted by them. This shall also be co-ordinated with the manufacturer of Generator.	
Turbine setting (Centre Line of Distributor)	-6.3 m (953. 7m)

1.2 Other Aspects & Requirements

Bidder shall compute pressure and speed rise using the parameters of plant and the operating conditions and furnish the detailed study/ calculations. The turbine shall be so designed/ constructed as would enable maximum assembly of components at works and at the same time permit easy transportation. The weights and sizes of the components/ packages shall be within the permissible transport limits for the project .

The bidder shall include the following information in their offers:-

- Turbine performance data, turbine capacity at heads in specified working head range; velocity diagrams with values of velocities and angles at runner inlet and outlet and absolute velocities at guide vane inlet at rated generator output, maximum 10% over load generator output net heads including optimal Design Head to be adopted by the Bidder.
- Safe part load operation limits at various heads, stable regime of operation and other essential data values of critical sigma and plant sigma for the range of operation.

The unit shall be designed to start up and shut down at least 2 (two) times a day. The maximum runaway speed at maximum net head shall be stated and guaranteed by the Supplier.

The generating unit shall be designed to withstand the forces and stresses occurring at maximum runaway speed condition for a period of at least 15(Fifteen) minutes without any damage and to safely withstand any transient over speeds.

The turbine shall be designed to give satisfactory, quiet and smooth operation, free from excessive noise, vibrations, pressure pulsations, power swings, hunting etc in the required range of operation of heads and outputs including overload output. Turbine design shall be such that it operates through its full range of specified conditions without vibration detrimental to its service life. The vibration amplitude at the shaft shall not exceed the values specified in ISO-7919 (Part-5).

The turbine shall be designed to meet the safety requirements in accordance with various applicable standards/ international practices.

The connection to the Penstock should be kept to a minimum. All penstock and Tail Water connections should be double valved. Wherever possible all connection to the Penstock and Draft

Tube should be embedded. All water carrying pipes should be provided with anti-condensation arrangements.

1.3 Standards

Unless otherwise stated, rating, characteristics, test and test procedures, etc. shall comply with the provisions and requirements of the latest applicable International Standards. The list of applicable standards shall be at least as described below in this section.

S.No.	Standard	Description
1.	IEC 60193	Hydraulic turbines, storage pumps and pump-turbines - Model acceptance tests.
2.	IEC 60609	Cavitation pitting evaluation in hydraulic turbines, storage pumps and pump turbines.
3.	IEC 60041	Field acceptance tests to determine the hydraulic performance of hydraulic turbines, storage pumps and pump- turbines.
4.	IEC 60545	Guide for commissioning, operation and maintenance of hydraulic turbines.
5.	IEC 60995	Determination of the prototype performance from model acceptance tests of hydraulic machines with the consideration of scale effects.
6.	ISO 7919 Part-5	Mechanical vibrations of non-reciprocating machines - Measurements on rotating shafts and evaluation criteria of machines set in hydraulic power generating and pumping plants.

1.4 Guarantees for Turbine Output, Efficiency & Penalties for Shortfall

The Suppliers shall provide turbines having the specified ratings and highest feasible efficiencies in the permissible range of operation. The turbine Bidder at bidding stage shall supply supporting documents for the prescribed guarantees by means of displaying results from earlier model tests of the model turbine which conforms as much as possible to the one now offered. The output and the efficiencies shall be guaranteed under penalty as given below.

The turbine output and efficiency shall be guaranteed by the Supplier.

The following requirements and rules for the guarantees apply:

i) Rated and Maximum Continuous output at rated net head (Minimum net head) of **60m.**

ii) Turbine efficiencies at following net heads in the specified working head range:

- Minimum Net Head,
- Best Efficiency Head &
- Maximum Net Head

a) Weighted Turbine Efficiency

The model and the prototype weighted turbine efficiency shall be guaranteed. The model average weighted efficiency will be calculated from the model efficiency using the following formula:

$$\eta_{a\,w} = 0.1 \times \eta_{110} + 0.7 \times \eta_{100} + 0.1 \times \eta_{80} + 0.1 \times \eta_{50}$$

Where,

$\eta_{a\,w}$ = Weighted average efficiency

η_{110} = Efficiency at 110percent of rated output when operating at rated net head

η_{80} = Efficiency at 90 percent of rated output when operating at rated net head

η_{50} = Efficiency at 50 percent of rated output when operating at rated net head

The prototype weighted average efficiency will be calculated from the model efficiency stepped-up to prototype efficiency according to IEC 60995, using the same grid of weights as above.

b) Efficiency Guarantee and Penalties

If the model weighted average efficiency on testing is less than the guaranteed weighted average efficiency the Contract Price for payment purposes, be decreased for each one hundredth of one percent drop in efficiency for each unit by 30000 USD:

Adjustments will, however, not be made until after the Supplier has been given an opportunity to correct the defects in performance. Modifications in design, if necessary, shall be made within a reasonable time not exceeding 3 (three) months so that the guaranteed performance can be obtained and the manufacturing shall commence only after satisfactory results are obtained in the model test.

In the event of extra time taken by the manufacturer for rectification of design deficiencies, the delivery schedule as agreed earlier shall be adhered to by the supplier. In case of failure to obtain satisfactory results to ensure guaranteed performance, the Owner reserves the right to cancel the contract or to accept the same subject to levy of penalty as specified above.

The model weighted average efficiency is the weighted average efficiency calculated from the model test results. If the model weighted average efficiency falls below the guaranteed figure by more than 2(Two) percentage point, then the turbine may be subjected to rejection.

i) For comparison of bids the weighted average efficiency as defined above will be used and for equalisation of bids loading at the rate of USD 15,000 shall be applicable for Turbine for each one hundredth of one percent lower weighted average efficiency for each unit.

c) Capacity and Efficiency Tests

Owner reserves the right to carry out capacity and efficiency test at different heads and gate opening on the prototype turbine within one year after commissioning to verify that the power output and efficiency guarantees of the prototype have been fulfilled.

The turbine efficiency and capacity tests shall be conducted in accordance with the provisions of IEC Publication 60041, International Code for Field Acceptance Tests of Hydraulic Turbines, under the supervision of a qualified independent expert, unless otherwise mutually agreed upon by the Supplier and the Owner. Any deviation from the IEC-60041 shall be clearly stated in the offer.

Efficiency shall be measured by the thermodynamic method or any other applicable method as mutually agreed between the Owner and the successful Bidder. Bidder shall furnish details of test method, agency which will conduct the test, provisions to be made for the field testing, calibration of instruments for the purpose of the test and all other relevant details in the offer. Bidder shall be under obligation to accept these tests for purposes of liquidated damages.

The Supplier shall make any subsequent adjustments in the turbine working parts as may prove necessary to secure optimum turbine performance.

d) Capacity guarantee and penalties

The Rated and Maximum Continuous Output Capacity at rated net head of 60m shall not be less than as specified above.

Penalty for one hundredth of one percent variation in output for each turbine unit below the guaranteed value will be applied as 60000 USD

For fractional values of the shortfall the penalty amounts will be computed on pro-rata basis.

The turbines not fulfilling the guarantees will be subjected to penalty by multiplying the penalties for one (1) turbine by the no. of turbines.

e) Cavitation guarantee

The Bidder shall guarantee the guide vanes, runner, discharge ring and other hydraulic passage of the turbine against excessive pitting caused by cavitation for the first 8000 hours of operation, or not over two calendar years after provisional acceptance of the turbine, whichever is the earlier. If the guarantee expires before 8000Hrs of operation the weight loss shall be on pro-rata basis.

The cavitation guarantee shall be as per IEC Publication 60 609.

Excessive cavitation pitting is defined as the removal of metal from the turbine runner, discharge ring, draft tube cone and guide vanes because of removal of material in excess of the weight defined by the following formula:

$W = 0.1 \times D_3^2$ per 1000 Hours of operation during the guarantee period defined above.

Where:

W = total permissible weight of metal in kilograms removed during the period of operation.

D_3 = Discharge Diameter of the turbine runner in meters.

1.5 Turbine Model Test

a) General

Before the supplier takes up the manufacture of the prototype turbine, test on homologous scale model of the prototype turbine shall be carried out to demonstrate that the prototype turbine will meet the guaranteed performance in respect of efficiency, output, smooth operation, pressure pulsations, and other guarantees as stipulated in the specifications.

b) Model Details, Drawings and Homology

Before taking up the manufacture of the model turbine, the Supplier shall submit to the Owner in a sequential manner, within 60 days after award of contract, drawings and description covering details of the proposed model, testing equipment to be used, instrumentation, testing procedure, method of interpretation and computation of test results for the approval of the Owner.

The turbine model shall be homologous to the prototype in all respects. The water passage of the model turbine shall be homologous with those of prototype right from the Spiral case inlet to the draft tube exit point. The draft tube cone shall be made transparent to permit observation of the vortex flow pattern and cavitation phenomenon and to take photographs of the same.

The model scale, minimum size and homology/ similarity to the prototype turbine shall be in conformity with the IEC code 60193.

c) Conducting of Model Test, Test Code, Submission of Report

The test shall be conducted in accordance with the IEC publications 60193. The test shall be completed and comprehensive test reports submitted for approval of the Owner within six (6) months after the award of contract.

The detailed programme of carrying out the comprehensive model test shall be intimated to the Owner Six weeks in advance of the start of the test for the Owner/consultant to depute their representatives for observation of the comprehensive tests.

d) Tests on Turbine Model

The test shall include:

Turbine performance (efficiency) tests.

- Cavitation tests with photo documentation.
- Runaway speed test.

- Pressure pulsation (fluctuation) tests for the draft tube frequency at half, full and over load.
- Hydraulic thrust.
- Guide vane torque.
- Air admission test for the full sigma range.
- To determine best location of the Winter Kennedy taps and to determine the exponent co-efficient for the flow calculation on prototype.
- The model test shall simulate all possible normal operating conditions of the prototype for the entire range of reservoir and tail water levels, guide vane openings, overload etc.

e) Step-up Formulae

The prototype efficiencies shall be calculated and derived from the model efficiencies as per the latest edition of IEC-60193 Code.

f) Presentation of Model Test Report

After the completion of the model test, the Supplier shall submit to the Owner, three copies of complete report, which shall include but shall not necessarily be limited to the following.

- Introduction, dates of test, by which it is conducted.
- Description of test equipment and test procedures.
- Drawings showing plan and cross section of the model turbine as well as the prototype turbine giving all principle dimensions and profile.
- Detailed drawings showing the complete set up of the test.
- Records of calibration of all test instruments and equipment.
- Record of all actual measurements made during the test viz. manometer readings, torque, speed, etc. which are used in the calculation of Head (H), Discharge (D), Speed (N), Power Output (P) etc.
- Comprehensive & complete sample calculation for each computation.
- Model efficiency curves covering entire operating zone.
- Curves showing sigma vs efficiency and sigma Vs unit power and unit discharge for specified head with envelope curves drawn.
- Curves showing relationship between guide vane angle and also guide vane opening in mm vs servomotor stroke related to maximum opening of guide vane and clear opening between two adjacent wicket gates.

- Prototype performance curves, hill charts and performance in tabular form for various operating conditions.
- Photographs and sketches of the cavitation phenomenon and vortex phenomenon with corresponding operating conditions.
- Pressure pulsation curves for various conditions of operation including air admission test.
- Establishment of hydraulic similarity of the model turbine to the prototype.
- Statements as to inaccuracy of each class of measurement and inaccuracy on combined measurement shall be indicated.
- A table showing the comparison of the test results with the guaranteed data, followed by technical conclusions.

g) Witness of Model Turbine Test by Owner's/ Consultants Representatives and Model Acceptance:

Along with the submission of the comprehensive model test report on the basis of test, the turbine supplier shall include a detailed programme (with at least 4 weeks advance notice) for actual demonstration of the correctness of the model test in the presence of Owner's representatives by repeating the tests at important points of operation as selected/ required by the Owner.

Should the model fail to meet the guarantees and requirements, it shall be optional for the Owner to conditionally accept the model and direct the supplier to modify the model until it complies with the requirements. All expenses involved for the modifications and subsequent model tests shall be borne by the supplier. Owner reserves the right to get the model turbine tested in an independent laboratory.