Revised Specifications for Hydro Power Plant Simulation Software

A. Vendor qualifying Norms:

1. Vendor should have an established presence for at least 10 years, with reputed clientele comprising of well known companies.
2. The author of the hydro power plant library should have at least 15 years of working experience in reputed companies and should have dealt with design and implementation of control systems for hydro power plants. The author should also have expertise in the use of digital simulation techniques for the testing of different control schemes for the hydro power plants. The expertise should include the simulation of cascaded hydro power plants, including the control systems.
3. The simulation software is proposed to be used for the simulation of two cascaded hydro power plants, for the purpose of testing the suitability of control schemes for tandem operation The upstream plant is operational, and the downstream plant is likely to be ready by 2012-13. The author of the hydro library should be available and committed to provide technical assistance in fine tuning the hydro models to match the site conditions, after the downstream project is commissioned.

B. Specification for the simulation software:

1. The software should be developed using either Simulink or Modelica only.

2. A proven hydro power plant library to be provided, which should comprise of the following component models as a minimum:

   - Reservoir- Should be possible to parameterize to any geometrical shape, can be discretised, and wave propagation due to transients should be covered.
   - Head Race Tunnel- Should be possible to parameterize to any geometrical shape, can be discretised.
   - A pipeline model using a TLM (transmission line modeling) approximation to wave propagation in pipes, penstocks and general closed conduits. This model gives a solution of the wave propagation according to the "Method of Characteristics" and includes friction losses.
   - Surge Shaft - . Should include a surge shaft connected to multiple penstocks.
   - Penstock- Should include penstock supplying multiple turbines connected in parallel, elastic & inelastic water column effects, water hammer, traveling wave effect to be covered..
   - A grid model to simulate the load. The grid model should have the option to add disturbances.
   - For control purposes simulation under no load, synchronization, load and load rejection should be possible.
   - Turbines & Generators- Should cover hydro turbine and generators, including the controls & protections. Francis, Kaplan and Pelton turbines to be included.
   - Tail race- Should include tail race tunnel, spillway, tail pond, tail pond outfall gates etc.
   - The above models should be complete and should enable simulation of any hydro power station and cascading of hydro power plants. Transient conditions should be simulated accurately. The mathematical basis for the above models to be provided in detail, and should help in establishing the accuracy of the models.

3. In the case of Modelica being used for the development of hydro library, the software tools should provide interface to Simulink , so that models in Modelica can be translated to Simulink.

4. Software tools should include the feature to generate source code in C language for the models.

5. Software should have compatibility to real time simulation hardware such as DSPACE & OPAL-RT at least.

6. In addition to the hydro library mentioned above, a model of the cascaded hydro plants described in the case study mentioned below should also be provided to enable validation of the software tools.

C. Training:

Training on the software tools may be indicated.

D. Delivery Clause:

Delivery should be strictly within four weeks of placement of firm order. No relaxation can be permitted. Fine tuning of the model for the case study given below can be carried out after delivery.

E. Acceptance Criteria:

1. The mathematical equations used for building the models will be evaluated for accuracy by comparing with the IEEE standard models established by the IEEE working group committee.

2. Described below is a case study of a cascaded hydro project which may be modeled & simulated for a typical condition. The simulation results will be used for the validation of the software. Additional information on the hydro project described in the case study will be provided on request. The model should include simulation of opening / closing of the outfall pond outlet gates at the rate of 4 m/s. A Tandem control system is proposed control the machines in the upstream and downstream hydro plants and the pond outlet gates. The purpose of the Tandem control system is to maintain the pond level at a “Null” position (say 1005 m) in steady state under all operating conditions. In transient conditions the water level in the pond should not go below (soffit of Rampur HRT + 1m) to prevent air entrainment. Also spillage is to be minimized from outfall gates / spillway. The Tandem control scheme should also be modeled. A simple scheme can be presumed for the purpose of validation.

F. CASE STUDY:

Implemented on the Satluj River in the North India and comprising the Nathpa-Jhakri Power plant upstream and the Rampur Power plant downstream, the Nathpa –Jhakri – Rampur Development perfectly fits the denomination of a Macro Cascade Diversion Scheme as:

- With its 405 m^3/s maximum capacity and its 1650 MW, it counts among the largest diversion hydroelectric projects world-wide.

- Between the Intake Weir at Nathpa and the outlet to the river of the Rampur power station tailrace channel, the whole head available is utilized and the diverted water never meet back the river bed, while the discharge continuity in the hydraulic system is not altered by secondary intakes.

The Nathpa-Jhakri is currently under exploitation, whereas the commissioning of the Rampur Powerplant is scheduled for 2012.

The salient technical features of the Nathpa-Jhakri and Rampur powerplants can be summarized as follows:

Nathpa-Jhakri

- Diversion dam: height x crest length: **60 x 170 m**
- Diversion dam storage volume: **3.5 10^6 m^3**
- Diversion dam spillway capacity: **5'660 m^3/s**

Diversion dam spillway gates: h x b: **5 radial gates 8.5 x 7.0 m**

- Desilting chambers: number x dim. l x h x b**: 4 x 575.0 x 27.5 x 16.3 m**
- Low Pressure Tunnel: diameter x length: **Ø10.15 x 27'300 m**
- Surge Shaft: diameter x height: **Ø21 x 301 m**
- Pressure shafts: number x diameter x length: **3 x Ø6 x 700 m**
- Power station maximum capacity: **6 x 275 = 1650 MW**
- Rated discharge: number of units x unit capacity: **6 x 64.7 = 388 m^3/s**
- Maximum discharge: **405 m^3/s**
- Rated head**: 428 m**
- Energy production: **6789 GWh/a**

Rampur

- Jhakri Outfall Pond: normal / minimum water levels: **EL 1005.00 / 1002.00**
- Jhakri Outfall Pond top of walls: **EL 1026.50**
- Outfall Pond storage between normal and minimum levels: **5000 m^3**
- Outfall Pond outlet gates: number x h x b **3 x 4.33 x 7.50 m**
- Spillway Tunnel outlet: invert / crest levels: **EL 1010.00 / EL 1016.00**
- Low Pressure Tunnel: diameter x length: **Ø10.50 x 15**
- Surge Shaft: diameter x height x orifice diameter**: Ø38 x 140 x 6.0 m**
- Pressure shafts: number x diameter x length: **3 x Ø5.4 359.7 m**
- Power station maximum capacity: **6 x 76.0 = 456 MW**

- Rated discharge, number of units x unit capacity: **6 x 64.7 = 388 m^3/s**
- Maximum discharge: **405 m^3/s**
- Net design head: **119 m**
- Tailwater: maximum / average / minimum **EL 866.7 / 864.8 / 862.9**

A scheme (in five parts) of the cascaded hydro plants is given at the end of the document for clarity. In the case of both hydro power plants, the surge shaft trifurcates into three pressure shafts, and each pressure shaft supplies two turbines.

The two power houses have to be operated in tandem, as the capacity of the outfall pond is only 5000 m^3 **,** there could be a risk of air entrainment in the low pressure tunnel of downstream plant, due to sudden evacuation. It is required to simulate and ascertain the functioning of the tandem control scheme. For this one would need to simulate both hydro plants, including the waterways. Transient conditions will have to be simulated, indicating the water levels in outfall pond, surge shafts, water hammer effects in penstock, etc.

Simulation of a typical condition:

- Simultaneous closure of all units at both power stations operating in overload conditions (106 % of the nominal capacity: 1.06 x 383.8 m^3/s = 406.8 m^3/s), it being the most critical event, particularly with respect to the risk of entraining air into the Rampur Low Pressure Tunnel.

The results of these numerical simulations may be given by plotting the graphs of discharge (Q) and hydraulic grade line level (H) at the following nodes:

- Node NIP (U/S element J0): Inlet section Jhakri Low Pressure Tunnel
- Node JST (top of element JS): Water level Jhakri Surge Shaft
- Node JTU (D/S of element J3): Inlet Jhakri turbines (Main Unit Valve)
- Node JTD /U/S of element DT: Outlet Jhakri turbines
- Node JOS (top of element TS): Water level Jhakri tailrace Surge Tunnel
- Node OPT (top of element OP): Water level Outfall Pond
- Node OST (top of element OS): Water level Spillway Tunnel
- Node RST (top of element RS): Water level Rampur Surge Shaft
- Node RTU (D/S of element R4): Inlet Rampur turbines (Main Unit Valve)
- Node RTD (U/S of element RO: Outlet Rampur turbines

For any Technical clarifications please contact –

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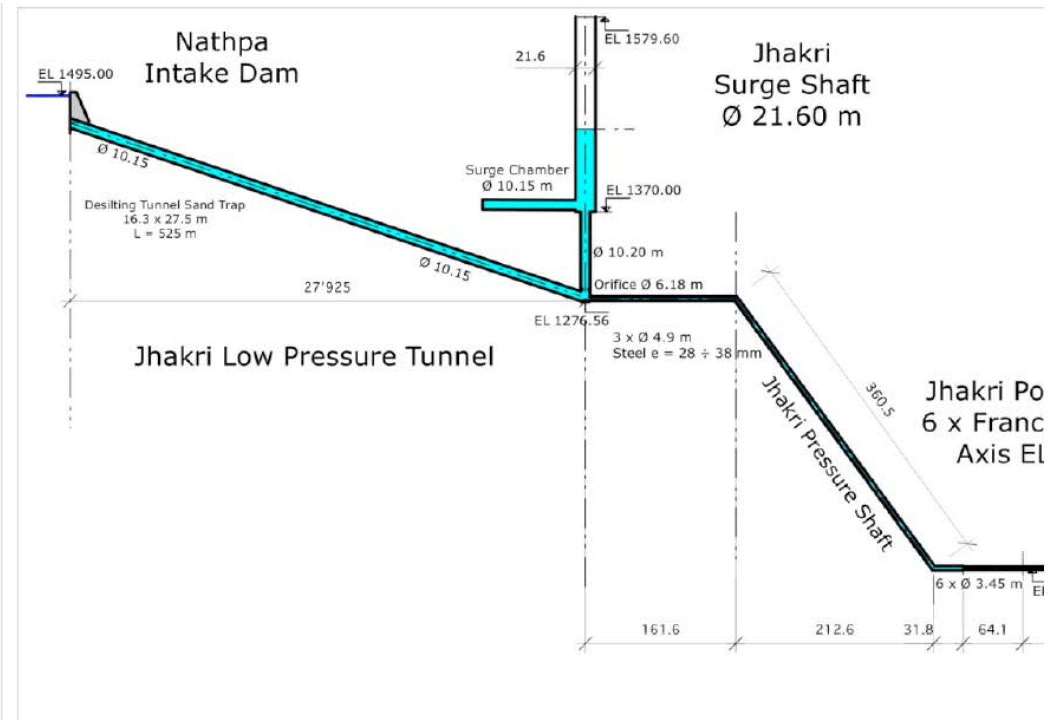
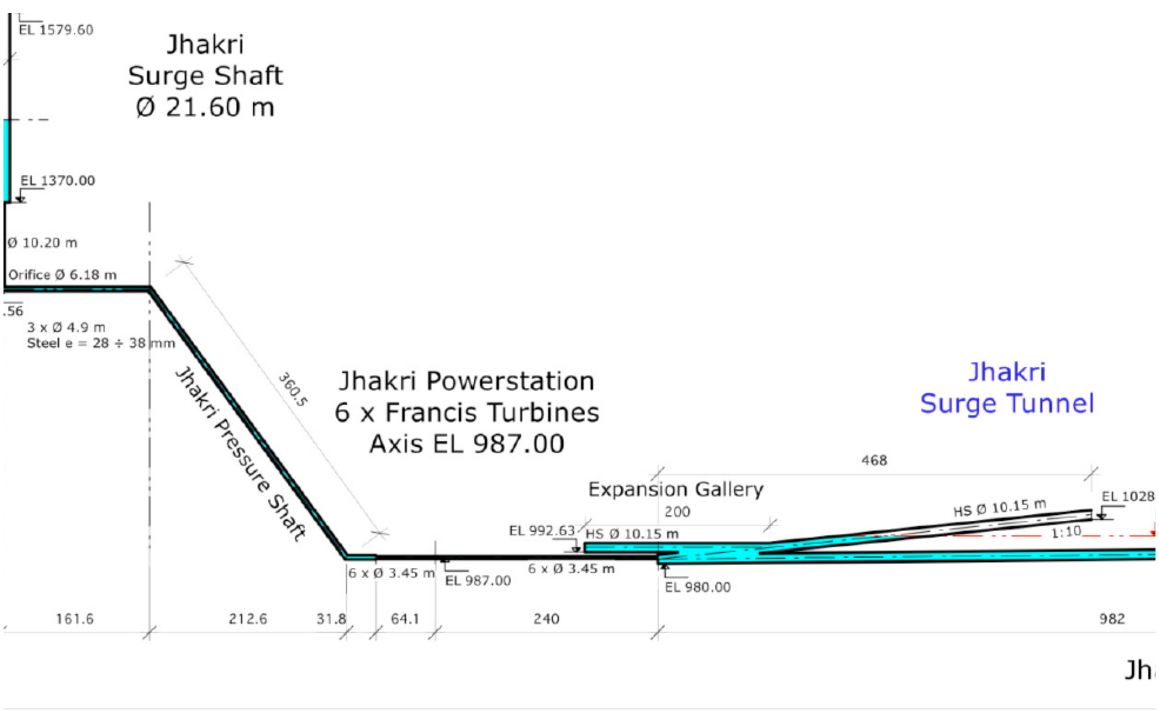
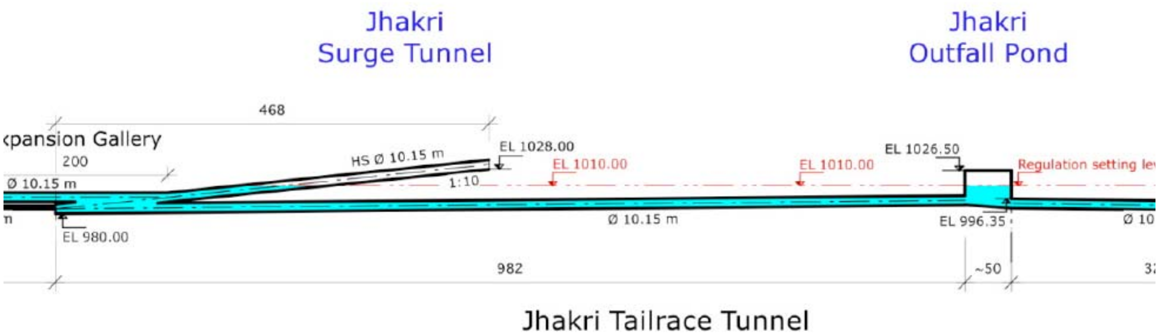
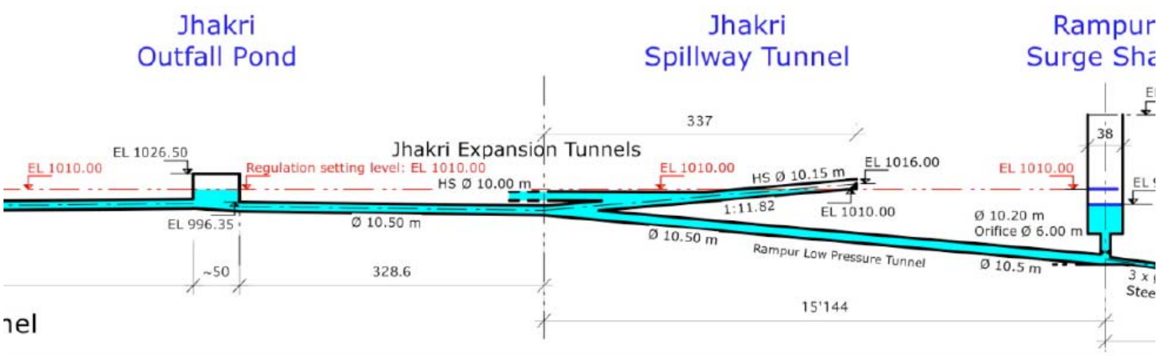

Nathpa
Intake Dam
EL 1495.00
Ø 10.15
Desilting Tunnel Sand Trap
16.3 x 27.5 m
L = 525 m
Ø 10.15
27'925
21.6
EL 1579.60
Jhakri
Surge Shaft
Ø 21.60 m
Surge Chamber
Ø 10.15 m
EL 1370.00
Ø 10.20 m
Orifice Ø 6.18 m
EL 1276.56
3 x Ø 4.9 m
Steel e = 28 ÷ 38 mm
Jhakri Low Pressure Tunnel
360.5
Jhakri Pressure Shaft
6 x Ø 3.45 m
161.6
212.6
31.8
64.1

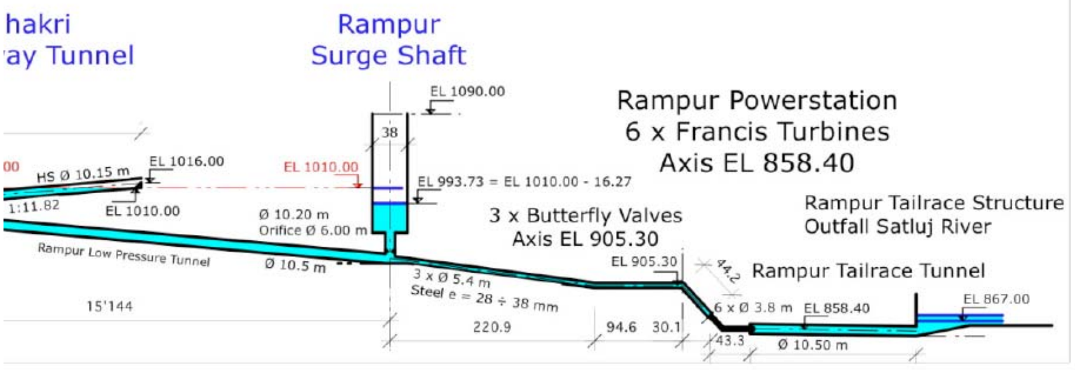

EL 1579.60
Jhakri
Surge Shaft
Ø 21.60 m
EL 1370.00
Ø 10.20 m
Orifice Ø 6.18 m
3 x Ø 4.9 m
Steel e = 28 ÷ 38 mm
360.5
Jhakri Pressure Shaft
Jhakri Powerstation
6 x Francis Turbines
Axis EL 987.00
Jhakri
Surge Tunnel
468
Expansion Gallery
200
EL 992.63
HS Ø 10.15 m
HS Ø 10.15 m
EL 1028
1:10
6 x Ø 3.45 m
EL 987.00
6 x Ø 3.45 m
EL 980.00
161.6
212.6
31.8
64.1
240
982



Jhakri
Surge Tunnel
Jhakri
Outfall Pond
468
xpansion Gallery
200
HS Ø 10.15 m
EL 1028.00
EL 1010.00
EL 1010.00
EL 1026.50
Regulation setting le
Ø 10.15 m
1:10
Ø 10.15 m
EL 996.35
Ø 10
EL 980.00
982
~50
Jhakri Tailrace Tunnel



Jhakri
Outfall Pond
Jhakri
Spillway Tunnel
Rampur
Surge Sha
337
38
EL 1026.50
Jhakri Expansion Tunnels
EL 1010.00
Regulation setting level: EL 1010.00
HS Ø 10.00 m
EL 1010.00
HS Ø 10.15 m
EL 1016.00
EL 1010.00
1:11.82
EL 1010.00
EL 996.35
Ø 10.50 m
Ø 10.50 m
Rampur Low Pressure Tunnel
Ø 10.20 m
Orifice Ø 6.00 m
Ø 10.5 m
~50
328.6
15'144
nel



hakri
ay Tunnel
Rampur
Surge Shaft
EL 1090.00
38
Rampur Powerstation
6 x Francis Turbines
Axis EL 858.40
00
HS Ø 10.15 m
EL 1016.00
EL 1010.00
EL 993.73 = EL 1010.00 - 16.27
1:11.82
EL 1010.00
Ø 10.20 m
Orifice Ø 6.00 m
3 x Butterfly Valves
Axis EL 905.30
Rampur Tailrace Structure
Outfall Satluj River
Rampur Low Pressure Tunnel
Ø 10.5 m
3 x Ø 5.4 m
Steel e = 28 ÷ 38 mm
EL 905.30
Rampur Tailrace Tunnel
6 x Ø 3.8 m
EL 858.40
EL 867.00
15'144
220.9
94.6
30.1
43.3
Ø 10.50 m