Sponsored by:
Ministry of New and Renewable Energy
Government of India

Alternate Hydro Energy Centre
Indian Institute of Technology Roorkee
Roorkee
INTRODUCTION

Real turbines can be tested at site in real conditions for which it is designed, only after installation and that too with relatively high inaccuracy. Practically no improvement can be done once the machine has been installed. The tests are therefore conducted on scaled models, on scaled hydraulic conditions. Such model tests process is a time consuming job and it demands well calibrated precision instruments, which are costly and often tailor made. Larger turbine manufactures such as BHEL, Andritz, Voith, GE and Dongfang have their own test facilities. However, smaller developers and consultants concerned with hydro power cannot afford such a big investment. Consequently, several projects have faced surprises during their operation.
HYDRAULIC TURBINE R&D LABORATORY, AHEC, IIT ROORKEE

A fully automatic SCADA based Hydraulic Turbine R&D Laboratory sponsored by Ministry of New and Renewable Energy, Government of India has been commissioned in 2017 at AHEC, IIT Roorkee, Uttarakhand. AHEC is a center of excellence for small hydropower in the country, to validate the homologous hydro turbine models designed & fabricated by various turbine manufacturers. IIT, Roorkee is one of the oldest technical institute set up in 1847 and has played an important role in the development of Water resources in India, both through education of competent engineers as well as research work.

OBJECTIVES

The laboratory shall support the Indian small hydropower industry (government as well as independent) to grow and compete in the International market in various aspects of hydroelectric power development:

1. Spearheading research and development activity in the country for hydro turbine.
2. Developing human resources for small hydropower in respect of entrepreneurs, engineers, plant operators and researchers.
3. Generating data and building expertise for solving site specific problems.
4. Providing affordable facility to small hydro manufactures for design verification.
5. Validating designs of small hydro turbine and layouts using CFD technique.
6. Developing and validating flow-measuring techniques leading to optimum utilization and generation.
7. Providing calibration facility for measuring instruments used for both, field-testing and power-plant operation.
8. Providing facilities for testing and certification of turbines.
The method used is simulating conditions similar to those around the runner of the turbine in a real hydro power plant. Two large VFD driven large pumps are used for varying the water discharge, head and measuring various parameters such as max power, max discharge, max head and Max speed.

HIGH-TECH FACILITY

Both experimental and field tests will be carried out to validate the forecast performance and output test results obtained by calculation methods. The experimental tests will be conducted for Francis and Kaplan turbine by using a scaled model of the turbine. This stage of the hydraulic testing process provides a unique opportunity to verify the complete turbine operating range, taking into account complex operating phenomena, which are not covered in the theoretical calculation and tests carried out in previous stages. This high-tech scaled model test laboratory is equipped with dedicated test-rigs for Francis and Kaplan turbine with provision of future extension for Impulse turbine. The test rig is capable of simulating Conditions identical to those in a real hydropower plant. The guiding parameters in setting up this Lab are as follows:

- Excellent overall accuracy in turbine efficiency measurement (target better than 0.25%)
- Repeatability (target better than 0.15%).
- Limiting the normal power consumption in the Laboratory to 300 kW level.
- Flexible rig to accommodate many types and designs of turbine models.
- Test conditions and parameters to be stable.

The key parameters measured on this test-rig are input water power i.e. head & discharge, output power i.e. runner speed and torque. This test-rig can measure power capacity up to 132 kW, for speeds up to 1000 rpm, with maximum test heads of 60m with discharge 150 l/s and minimum test head of 15m with 950 l/s.

TESTS ON SCALED MODEL

- Weighted average efficiency and turbine output
- Cavitation's performance
- Pressure pulsation
- Run away speed

Besides above following tests will also be conducted:

- Characteristic Curves for the Turbine Quadrant
- Hydraulic Thrust
- Torque

The laboratory is equipped with state of the art SCADA based automatic control system with electromagnetic flow meters, pressure transducers and sensors. The Laboratory has flow measurement tank and calibration tank. There will be a provision to calibrate the instrument against weight of water.
<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Max Head m</strong></td>
<td>60 m with discharge 150 lt./s. (Both pumps in series)</td>
</tr>
<tr>
<td><strong>Max, discharge l/s</strong></td>
<td>950 l/s at head of 15 m (Both Pump in parallel)</td>
</tr>
<tr>
<td><strong>Max speed</strong></td>
<td>1000 RPM</td>
</tr>
<tr>
<td><strong>Hydro Static Bearing</strong></td>
<td>Voith, Germany Make</td>
</tr>
<tr>
<td><strong>VFD</strong></td>
<td>Siemens Make</td>
</tr>
<tr>
<td><strong>Universal Frequency counter/timer</strong></td>
<td>Agilent Make, 350 MHz, 12 digits, 100 PS</td>
</tr>
<tr>
<td><strong>Weights</strong></td>
<td>Calibrated F2-Class Standard weights</td>
</tr>
<tr>
<td><strong>Calibration</strong></td>
<td>Gravimetric (Weighing)</td>
</tr>
<tr>
<td><strong>Flow measurement</strong></td>
<td>ABB Make Electromagnetic Flow meter, velocity range 0-10m/s (max.)</td>
</tr>
<tr>
<td><strong>Head measurement</strong></td>
<td>Yokogawa Make Differential pressure Transmitter</td>
</tr>
<tr>
<td><strong>Torque measurement</strong></td>
<td>By HBM Make T12 torque meter and HBM Make Z6 Load cell</td>
</tr>
<tr>
<td><strong>Speed measurement</strong></td>
<td>By HBM Make T12 torque meter</td>
</tr>
<tr>
<td><strong>Measuring Tank and calibrator tank</strong></td>
<td>Measuring tank; 3 Nos. 22T capacity RTN Type, HBM Make load cell,</td>
</tr>
<tr>
<td></td>
<td>calibrator tank; 1No. 2T Capacity, S-type HBM Make load cell</td>
</tr>
<tr>
<td><strong>Cavitations number Measurement</strong></td>
<td>Yokogawa Make Diff. pressure transmitter</td>
</tr>
<tr>
<td><strong>Size of turbine model</strong></td>
<td>Runner 350 mm for Francis Turbine</td>
</tr>
<tr>
<td></td>
<td>Runner 350 mm for Kaplan Turbine</td>
</tr>
<tr>
<td><strong>Flow calibration loop</strong></td>
<td>Can also be configured as calibration loop by by-passing the rig through</td>
</tr>
<tr>
<td></td>
<td>diverter unit in measuring tank/discharge tank.</td>
</tr>
<tr>
<td><strong>Model testing</strong></td>
<td>Closed loop</td>
</tr>
<tr>
<td><strong>Reservoir size and capacity</strong></td>
<td>12.1mx8mX4.45m, Volume 217.8m³</td>
</tr>
<tr>
<td><strong>Sump size and capacity</strong></td>
<td>12.1mx7.1mX4.45m, Volume 300.69m³</td>
</tr>
<tr>
<td><strong>Transfer pumps motors-4 nos.</strong></td>
<td>WPIL Make, Water lubricated, Speed 1450 rpm, Cap 900 m³/hr, total head</td>
</tr>
<tr>
<td></td>
<td>3.0m Motor: ABB Make</td>
</tr>
<tr>
<td><strong>Main pump-motor -2 nos.</strong></td>
<td>WPIL Make, Pump: Suction 400NS, Discharge 350NS, Speed 988rpm, Capacity</td>
</tr>
<tr>
<td></td>
<td>1440 m³/hr, total head 24m Motor: 160 kW, 988 rpm, V415 V, Siemens Make</td>
</tr>
<tr>
<td><strong>Dynamo-motor and Fourth quadrant</strong></td>
<td>Simons Make 132kW AC Drive and induction motor</td>
</tr>
<tr>
<td><strong>VFD</strong></td>
<td>kirlosker Make, 415V, 50Hz, 0.85 pf, 11 kW, 1470 RPM</td>
</tr>
<tr>
<td><strong>Side Channel Pump-1no.</strong></td>
<td>Speck-Pumpen, Germany Make, 415V,50Hz, 0.85 pf, 1.5 kW, 1440 RPM</td>
</tr>
<tr>
<td><strong>Liquid Chiller</strong></td>
<td>Drycoo systems Make, 40TR, water temp. 31°C max.</td>
</tr>
</tbody>
</table>
Flowmeter calibration system

1. 0.5 Ton calibration tank and 1 No. 2.0 Tons weight S40A load cell used, which is calibrated by the F2 class standard weights.
2. 10 Tons measuring Tank (weighing tank) and 3x22 Tons RTN load cell used, which is calibrated by the 2.0 ton calibration tank.
3. Flow Diverter unit is operated by a Compressor
4. High accuracy precision timer used for actual time counter up-to-12 decimal in Flowmeter calibration
MEASUREMENT AND CALIBRATION FOR HEAD

HEAD MEASUREMENT SYSTEM

Head measurement and calibration SCADA screen

Pressure and suction transducers

Head measurement Panel
TORQUE MEASUREMENT AND CALIBRATION SYSTEM

Shaft Torque Calibration System

SPEED MEASUREMENT AND CALIBRATION SYSTEM

Measurement of Turbine Speed by rotary Speed transducer

Friction Torque Calibration system

1. Friction torque is measured by 10 kg load cell and calibrated by F2 class standard weights.
2. Shaft torque is measured by 2 kNm torquemeter and calibrated by F2 class standard weights.

Speed Calibration System
VARIABLE FREQUENCY DRIVE WITH MOTOR

Main Pump and motor with VFD (SINAMICS G120-Siemens)

Four quadrant dynamometer with VFD (SINAMICS S120-Siemens)
SUPervisory control and data acquisition

Data acquisition, control and operation of model testing are done by PLC based SCADA system. Results and graphs related to model as well as prototype are plotted simultaneously in NI-Labview System.
VOYTEX AND FLOW PATTERN OBSERVATION SYSTEM

Latest image watching instruments like High speed camera, Stroboscope and Borescope are used for observation.

Observation of the incipient Cavitation on Runner Blade

Visualization of flow pattern inside draft tube using High Speed Camera

Observation of the Channel Vortex from Runner Inlet

Observation of the Cavitation bubbles Inside Draft tube cone
### System Details

**Master Node:** 1 no. IBM x3550 M4 Server

<table>
<thead>
<tr>
<th>Description</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intel XEON processor E5 2680 (20 cores)</td>
<td>@ 2.8 GHz, 25MB Cache, 1200 MHz</td>
</tr>
<tr>
<td>2 numbers IBM 600GB HDD SAS 10K RPM</td>
<td></td>
</tr>
<tr>
<td>64GB DDR3 1866 MHz</td>
<td></td>
</tr>
<tr>
<td>1 No’s Dual Port FDR HCA Infinite band.</td>
<td></td>
</tr>
<tr>
<td>4 numbers Quad Gigabit Ethernet port.</td>
<td></td>
</tr>
<tr>
<td>1 number IMM port</td>
<td></td>
</tr>
<tr>
<td>1 number DVD RW drives</td>
<td></td>
</tr>
</tbody>
</table>

**Storage Node:** 2 nos. of IBM x3550 M4 Server

<table>
<thead>
<tr>
<th>Description</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intel XEON processor E5 2609 V2 (2x4 core)</td>
<td>@ 2.5 GHz, 10 MB Cache, 1200 MHz</td>
</tr>
<tr>
<td>2 No’s IBM 300GB HDD SAS 2.5”</td>
<td></td>
</tr>
<tr>
<td>32 GB DDR3 1833 MHz</td>
<td></td>
</tr>
<tr>
<td>1 No’s of HCA Infinite band quad port</td>
<td></td>
</tr>
<tr>
<td>2 numbers Gigabit Ethernet port</td>
<td></td>
</tr>
<tr>
<td>1 number IMM port</td>
<td></td>
</tr>
</tbody>
</table>

**Compute Node:** 12 nos. of IBM x3550 M5 Server

<table>
<thead>
<tr>
<th>Description</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intel XEON processor E5 2680 (2x12 core)</td>
<td>@ 2.5 GHz, 30MB Cache, 2500 MHz</td>
</tr>
<tr>
<td>1 No’s 500GB HDD 7200 RPM SATA 2.5”</td>
<td></td>
</tr>
<tr>
<td>96 GB DDR4 2133 MHz</td>
<td></td>
</tr>
<tr>
<td>1 No’s Dual Port HCA FDR Infinite band</td>
<td></td>
</tr>
<tr>
<td>Dual Gigabit Ethernet port</td>
<td></td>
</tr>
<tr>
<td>1 number IMM port</td>
<td></td>
</tr>
</tbody>
</table>
SOFTWARE INSTALLED ON HPC SERVER

1. Ansys-17
2. Matlab

RESEARCH SCOPES

In hydraulic turbine R&D laboratory of AHEC, IIT Roorkee, the research fields include multi-phase hydrodynamics, water power project, hydraulic machinery etc. At present, mostly research scopes are shown as follows:

- Computational analysis of intensity of hydraulic turbine.
- Application research of hydraulic optimization and analysis of internal flow.
- Flow field display technique of hydraulic turbine.
- Model test and acceptance test inland and overseas.
- Research on cavitation mechanism and anti-cavitation measures.
- Measurement and control technique for measurement of pressure fluctuations in hydraulic turbine.
- Hydraulic vibration stability test in hydraulic machinery.
- Measurement of dynamic pressure velocity field in hydraulic turbine.
NATIONAL ACCREDITATION BOARD FOR TESTING AND CALIBRATION LABORATORIES

ACCREDITATION CERTIFICATE


NABL is part of Asia Pacific Laboratory Accreditation Cooperation (APLAC) which in turn is part of International Laboratory Accreditation Cooperation (ILAC).
Hydraulic Turbine R&D Laboratory
Alternate Hydro Energy Centre,
Indian Institute of Technology Roorkee
Roorkee 247 657
Distt. Haridwar, Uttarakhand, India

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hturbinelab@iitr.ac.in; hturbinelab@gmail.com; akumafah@iitr.ac.in
The ‘Hydraulic Turbine R&D Laboratory’ at the Alternate Hydro Energy Center, IIT Roorkee will be inaugurated by

Shri Raj Kumar Singh, Honorable Minister of State (Independent Charge) Power, New & Renewable Energy, Government of India

on 10th April 2018, in the presence of Prof. Ajit Kumar Chaturvedi, Director, Indian Institute of Technology Roorkee.

You are cordially invited to attend the inaugural function in the multi activity centre scheduled at 3:30 pm on April 10, 2018.

A brief description of the laboratory is as follows:

Hydraulic Turbine R&D Laboratory at AHEC IIT Roorkee

With the support of Ministry and New Renewable Energy, Govt. of India, Alternate Hydro Energy Centre (AHEC), Indian Institute of Technology (IIT), Roorkee has established an international-level hydro turbine R&D laboratory as design and validation facility in addition to conducting research in hydro turbines and other hydro mechanical equipment conforming to national and international standards.

The laboratory is the first independent facility in the country and shall meet long felt needs by serving small as well as largescale hydropower government and private hydropower generating companies and turbine manufacturers in India and foreign countries. The laboratory shall be able to conduct tests on scaled models of hydraulic turbines, for efficiency, output, cavitation performance, pressure pulsation and runaway speed, characteristic curves for the turbine quadrant, hydraulic thrust and torque. The laboratory is equipped with state of the art SCADA based automatic control system with first principal based flow measurement, precision pressure transducers and sensors.

The laboratory has been granted by National Accreditation Board for Laboratories (NABL) accreditation as per ISO/IEC 17025:2005 for fluid flow testing as well as calibration vide certificate no. TC-6862 and CC-2532 respectively in Feb 2018. NABL is part of Asia Pacific Laboratory Accreditation Cooperation (APLAC) which in turn is part of International Laboratory Accreditation Cooperation (ILAC). The operation of the laboratory is as per IEC-60193. This is the first laboratory in the institute receiving the accreditation by NABL.

The laboratory will have the role of verification/validation of designs and generation of design data, third party test as a neutral laboratory, witness tests on turbines as a neutral agency and testing of most of reaction turbines. Laboratory will also carry out validation of designs through CFD technique.

MNRE has sponsored the establishment of this laboratory with revised outlay of Rs. 27.27 crore.

HIGH TECH. FACILITY:
Both experimental and field tests will be carried out to validate the forecast performance and output test results obtained from calculation methods. The experimental tests will be conducted in the Francis and Kaplan turbine and using a scale model of the turbine. This stage of the hydraulic testing process provides a unique opportunity to verify the complete turbine operating range, taking into account complex operating phenomena, which are not covered in the theoretical calculation and tests carried out in previous stages. This high-tech scale model test laboratory will be equipped a dedicated test-rigs for Francis and Kaplan turbine with provision of future extension for Impulse turbine, capable of simulating Conditions identical to those in a real hydropower plant.

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