Turbine Testing Laboratory and its Role in Hydropower Development

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Abstract: With the increase in project developers, manufacturers and independent power producers, there is increasing demand for the quality, performance and reliability of the components and system. Occasionally there are disputes between these parties in term of life and efficiency. Normally, local manufacturers adopt foreign design, which may not be best for the local condition due to several reasons. One prominent example of such problem is sand erosion of turbines and other components. In the absence of test facilities in the country, there is not significant contribution in design, modification and performance analysis of hydro power turbines in Nepal.

The Turbine Testing Laboratory of capacity 300 kW is proposed at Kathmandu University, which can test scaled model of large size turbines. The activities in the Turbine Testing Laboratory are: Performance testing of hydraulic turbines, pumps and other hydro-mechanical components, Developments of new turbines, education and training, and applied research to solve problems of hydropower industry

Turbine Testing Laboratories have played significant role in development of hydropower in several countries. The proposed laboratory at Kathmandu University is also expected to contribute for hydropower development in Nepal.

Key words: Hydraulic turbine, test laboratory, turbine performance, sand erosion

Background

There is a great need of and scope for hydropower development in Nepal. The global and regional economic liberalization trend in the late eighties led the Nepalese government to formulate a Hydro-Power Development Policy (1992), which opened the door to national and foreign private sector investment. As a result of that several small and large hydropower projects are being jointly promoted by Nepalese and foreign companies and many are in the pipeline. The rate of development of micro and small hydropower projects is also increasing in recent years. The Government of Nepal has announced ambitious plan to develop 10,000 MW in 10 years. Micro and mini hydro projects are equally important for rural electrification. The Energy Sector Assistance Program (ESAP) is concerned about the performance and efficiency of locally manufactured turbines. The Alternative Energy Promotion Center (AEPC) has now a policy of subsidizing plants of up to 1 MW under the Mini-Grid program, and for this there is a need of improvement in the competence of local turbine manufacturers up to that capacity.

Nepalese companies are capable of designing, manufacturing, installing and operating such micro hydro systems. With the increase in project developers, manufacturers and independent power producers, there is increasing demand for turbine quality, performance and reliability. Competence to exploit water resources for hydropower not only depends on financing, design and management of projects but also on knowledge generation and local adaptability of technology. There is an institution, Hydro Lab Pvt. Ltd. for physical and civil engineering modeling of hydraulic systems, but there is no institution to carry out research and development of hydro-mechanical components.

This paper reviews the contribution of the anticipated Turbine Testing Laboratory (TTL) for hydropower development and presents this project under development at Kathmandu University (KU), Nepal.

Need for a turbine testing laboratory in Nepal

Occasionally there are disputes between manufacturers, installers and customers related to turbine performance in terms of life and efficiency. The lack of performance data about locally manufactured turbines is undermining confidence in local products. Normally, local manufacturers and their agents adopt a foreign design, which may not be best suited to the local condition due to several reasons. One prominent example of such a problem is sand erosion. In the absence of a suitable Nepalese test facility significant contributions and corrections to the design, modification and performance analysis of hydropower turbines in Nepal are not available.

Building the turbine testing laboratory is justified by the following points:

- A TTL is needed for:
  - certification of mini- and micro-turbines sold on the Nepali market
  - supporting Nepali industry for product development
  - private testing by local manufacturers
  - independent performance testing of model turbines on behalf of owners
- To build competence and knowledge within the hydropower sector in Nepal to develop professional expertise at the highest level (Master in Engineering, PhD etc.), the TTL is needed:
  - as a teaching/learning facility
  - for industrial courses
  - for industrial staff training
- For motivating research:
  - for the development of very efficient hydro-turbines that

can withstand the most severe operating conditions. One such vexing problem is sand erosion, which is a major problem in Himalayan regions. Nepal can be centre of excellence in this field of research.

- – for development of turbine and pump technology
- – for maintenance of turbines
- To provide a meeting place between industry and university:
- – for research and student projects initiated by industry
- – to stimulate collaborative research with national and international universities and research institutions

Until now, model testing of turbines purchased by Nepal Electricity Authority (NEA) and other Independent Power Producers (IPP) is either carried out by foreign laboratories or it has not been done at all. Nepal Hydro Electric Pvt Ltd (NHE) has tested turbines for certification of their product for the Indian market. The competence of Nepalese companies in cross-flow turbines is due to testing of the turbines made by Balaju Yantra Shala (BYS) to design T12 specifications at Hong Kong Polytechnic with Swiss assistance (SKAT). With the establishment of the Turbine Testing Laboratory, such testing can be done within the country. This will help stimulate investment in hydropower, save money of both client and manufacturer and will enhance confidence in procured turbines.

Requirements of turbine testing laboratory

Data on the efficiency and output of a turbine are both determined in the laboratory, which must ascertain that tests are carried out under controlled conditions. The TTL therefore must be able to produce stable conditions of flow, head and load. It must be flexible enough to accommodate a wide range of turbine designs and types.

The most widely accepted standards related to large hydropower projects are mainly developed according to standards developed by the International Electro-technical Commission (IEC). Some IEC standards relate to mini-hydro projects and machines. But a widely accepted set of standards for micro-hydro hardly exists. For example, the widely accepted standard for turbine testing, IEC 41, states: *no leakage or addition of water may occur between the flow measuring instruments and the model (turbine).* The criteria should be easily verifiable. Stringent test conditions can only be achieved in an appropriate laboratory having minimal frictional and hydraulic losses and well calibrated instruments. To create such a facility at an actual power plant would be difficult and generally very expensive.

Turbine testing practices

Hydropower and turbine technology is generally well developed. Designers have excelled to reach theoretical limits of efficiency in large Pelton, Francis and Kaplan turbines. Further development can improve efficiencies by less than one percent, but even such small improvement can be significant for large capacity turbines. Hence universities, research institutes and manufacturers want to continue to carry out research on turbine performance, manufacturing, materials and operational strategies.

Large turbines cannot be tested at site and in the real conditions for which they are designed. Rather, testing has to be done on scaled models using scaled hydraulic conditions. Larger turbine companies have their own test facilities. On the other hand, independent turbine testing for performance guarantees has become international business. Some of the turbine laboratories owned by turbine companies are:

- Sulzer Hydro
- Rainpower (Formerly Kvaerner)

There are some independent or university owned laboratories. These laboratories, used for research, development, education and training, include

- MHyLab Mini-Hydraulics Laboratory, Switzerland
- Water Power Laboratory, Norwegian University of Science and Technology (NTNU), Norway
- Laboratory for Hydraulic Machinery (LHM), EPFL, Switzerland
- Turboinstitute, Croatia
- Alternative Hydro Energy Centre, Roorkee, India
- Central Water and Power Research Station, Poona, India
- MA National Institute of Technology, Bhopal, India

The facilities available in such laboratories are being used not only for research but also as means to generate revenue for universities. Turboinstitute in Croatia has been providing turbine testing services for the last 60 years and has experience of model acceptance tests of more than 100 turbines (Kercan 2008). LHM-EPFL in the last 40 years not only has been dedicated to Swiss companies but is providing service to North American hydropower industries (Avellan 2008). Since 2004, it has carried out model testing for more than 42 projects ranging from 18 MW to 770 MW.

The NTNU Water Power Laboratory, established in 1917, was instrumental in the development of hydropower in Norway. This laboratory was refurbished and modernized in 2001. Testing facilities at this laboratory are often rented by turbine companies such as GE and Rainpower. The concepts developed in this laboratory have already created two successful spin-off turbine companies. KU has close collaboration with this laboratory for lab development, human resource training and laboratory use for contract research.

Some micro hydro turbines are tested in university laboratories either as student research projects, or funded by technical aid programs. Los Arides University in Columbia has done testing of Peltrics made by local manufacturers. Similarly, the UK Department for International Development (DFID) sponsored Nottingham Trent University to develop picohydro units (Thake and Shrestha 2001).

In Nepal, test facilities were established at BYS and BEW (NHE premises) for cross flow turbines. But these facilities are not in service at present. NHE has also used its test facilities to develop small pico-turbines (propeller type). The micro-hydro turbine manufacturing companies Kathmandu Metal Industries and Powertech Pvt. Ltd. have also developed their own rig for product testing. The Center for Energy Studies, Institute of Engineering, of Tribhuvan University has got a test facility for cross flow turbines. Graduate and undergraduate students of TU are using this laboratory for their thesis work.

Turbine Laboratories at Kathmandu University

KU began developing concept studies for a turbine test facility in 1997 in association with the Rural Energy Development Programme (REDP 1998). During 2000/2001 KU began designs for a major turbine testing laboratory to be installed at Dhulikhel, Nepal in co-operation with the Energy Sector Assistant Program (ESAP) for whom a feasibility study carried out by IT Power, UK, recommended KU as the best institute at which to have a turbine testing facility (Thake and Shrestha 2001).

At this time KU has two miniature turbine laboratories. The rebuilt Pico Turbine Laboratory is dedicated for research and development of axial IGV/axial flow pico propeller turbines (Cannell *et al* 2005), of powers up to 2 KW. It has produced one low-cost 800W pico set having 90% overall efficiency and is now developing a similar 1.5kW set, also amenable to mass-production at low cost. The primary intention of this R&D was to understand

(a) **(b)** **(c)**

Figure 1. Research at the miniature turbine laboratory at Kathmandu University: (a) Flow visualization in Pelton bucket, (b) Pressure distribution analysis inside the bucket, (c) sand erosion test of stainless steel and HVOF coating.

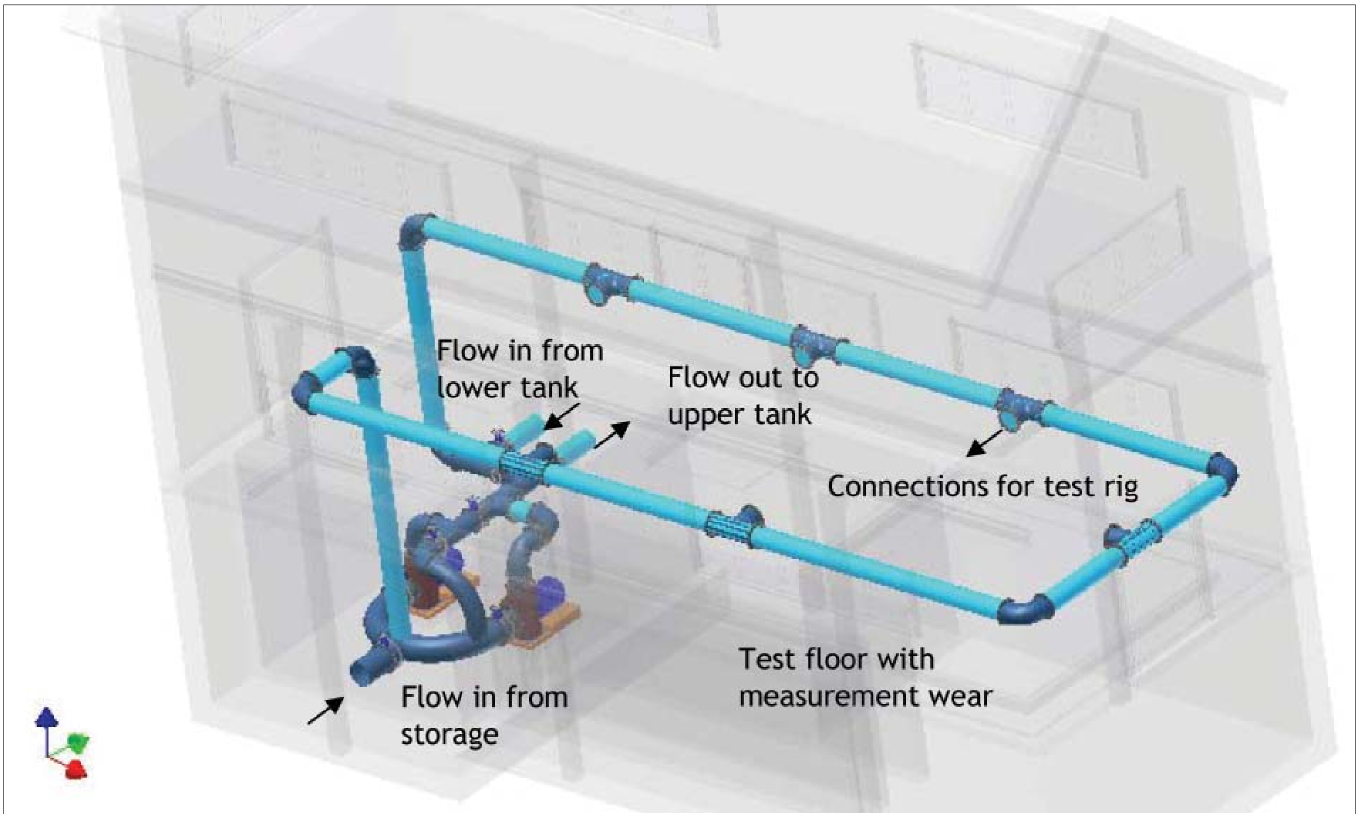

Figure 2. Piping and Pump Arrangement of Turbine Testing Laboratory

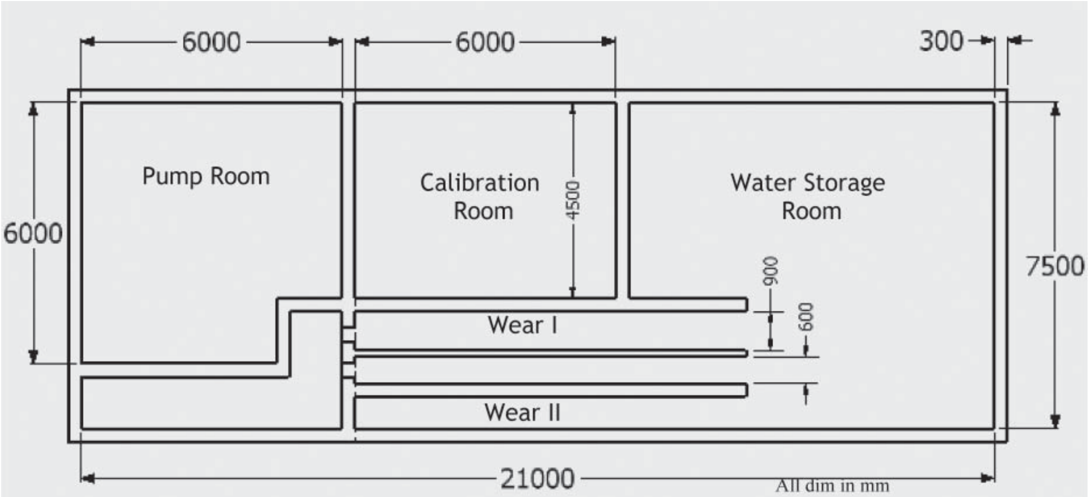

Figure 3. Test Floor Layout

axial head variations, correct annulus areas and radial flow variations by which more exact blade angles can be designed. Testing dominates now.

The Water Power Laboratory is dedicated to performance analysis of Cross-flow and Pelton turbines and to associated training. This laboratory is also used for research on issues related to sand erosion of turbine components. Five different Pelton bucket profiles designed at KU are being performance tested for impact and flow visualization (Figure 1a). The bucket contours are generally designed to give accelerations of particles normal to surfaces (Brekke 2001). A bucket profile with elliptical to slightly linear cross-section in both longitudinal and lateral cross sections showed maximum momentum transfer (Thapa et al 2006). The pressure distribution around the bucket (Figure 1b) justified the better performance of this bucket (KC 2008). The sand erosion test carried out at Rotating Disc Apparatus (Chaudhary 2008) for the stainless steel and HVOF-coated WC-Co-Cr coating used in Kaligandaki hydropower project, Nepal compared performance of HVOF coatings with steel (Figure 1c). This provided an opportunity for accelerated sand erosion testing for a comparison of different materials (Thapa 2005).

Turbine Testing Laboratory

The major KU Turbine Testing Laboratory (TTL) at Dhulikhel will have a main system connecting lower and upper reservoirs to circulate water (rainwater) to run turbines (Figure 2). The topography of the laboratory location (at the main campus) provides 30m natural static head, which is a unique feature of such a test laboratory, and will be of direct use for some turbine tests. The water from the lower reservoir will be re-circulated to the upper reservoir by two pumps of 160 kW, head 75 m, flow rate 0.25 m^3/sec. The laboratory will be equipped with a state-of-the-art control system with electromagnetic flow meters, pressure transducers and sensors. With this system, the largest turbine that can be tested will be 300 kW. The two pumps can be operated in series and parallel circuits to obtain different operational regimes to simplify the testing of a variety of turbine capacities and generated heads.

The TTL floor will have flow channels incorporating flow measurement (Figure 3). There is also flexibility to install any type of turbine in the test rig. Both flow and head stability and the accuracy of the measurement system are very important for the quality and accuracy of the test results achieved. Hence the instruments and sensors will be regularly calibrated. There will be a provision to calibrate appropriate instruments against weight of water. The system will be able to test both reaction and impulse turbines (Figure 4).

The estimated cost of development of the laboratory is about 85 million Nepalese Rupees (about US$1.11 million). KU is willing to contribute up to 20% of the cost and is persuading NORAD and Nepalese industries to contribute to the remaining development. The lab will be operated on business principles under the direction of a board representing KU and other stakeholders.

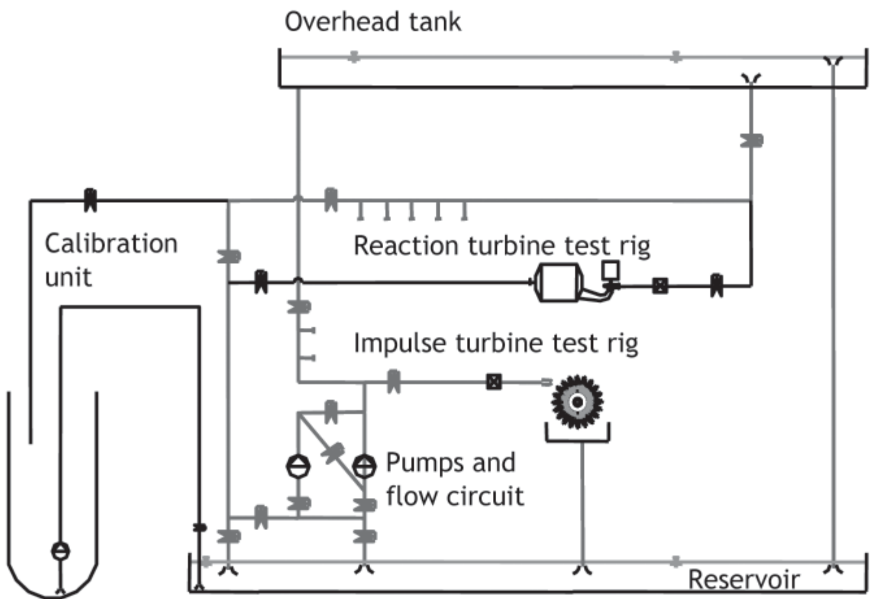

Figure 4: Schematic layout for turbine testing and calibration arrangement

This will be a major national asset for sustainable hydropower development in Nepal.

Conclusion

Turbine laboratories have played a very significant role in the development of hydropower in different countries. Such laboratories have a vital role in research, development, training and education. Turbine performance testing has become an international business. Several universities own turbine laboratories for research, training and development. Such laboratories are also used for helping to meet local operational challenges such as sand erosion. KU has envisioned and designed a turbine testing laboratory at Dhulikhel which will have the capacity to test turbines of up to 300 kW. Model tests can be handled for bigger projects based on scaled-down models. The estimated cost of NRs 85 million (about US$1.11 million) can be recovered in a fairly short period of time by providing expert and versatile test services to turbine manufacturers and power companies. Beyond that the TTL will help produce high levels of human resource and training for the South Asian and Nepalese hydropower industry.

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Acknowledgement

The authors acknowledge the contribution of Mr Raju Shrestha and Mr Biraj Singh Thapa for initial design and drawing of the TTL.