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# Development of a Francis Turbine Test Rig at Kathmandu University-I

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## Abstract

The objective of the master thesis is to design a complete system for the efficiency measurement of Francis turbines in the Turbine Testing Laboratory (TTL) at Kathmandu University with a special focus on the measurement and calibration for friction torque and axial load. A bearing block for the Francis turbine test rig will be designed, along with a measurement system for the axial load. Detail 3D-drawings for the main components in the test rig will be made. In the preliminary project to the thesis, piping and instrumentation diagrams for the Francis rig at TTL have been developed. Open and closed loop configurations are exemplified. Calibrations of the instruments are limited to principal methods in compliance with *IEC60193*. Differential pressure transducers that are calibrated by a deadweight manometer measure the differential pressure between the turbine inlet and outlet. An electromagnetic flowmeter calibrated by the weighing method measures the volume flow rate. In conjunction with the main shaft are arrangements for measuring the generator- and friction torque, axial thrust and rotational speed.

**Keywords:** Hydropower, TTL, Francis

## 1. Introduction

Snowmelt from the Himalayas, rainfall on mountainous terrain and a large number of rivers are among the reasons why Nepal's hydropower potential is enormous. The theoretical capacity for Nepalese hydropower production is estimated to be over 80,000 MW, of which 44,000 MW are economically viable [2]. As of 2014, installed capacity was 700 MW versus a demand of over 1,000 MW that is increasing with 7-9% per year [2]. The combination of a domestic demand-supply gap and a vast export potential through the Power Trade Agreement (PTA) with neighboring India, suggests that large investments will be made towards realizing projects for exploiting some of the large number of untapped resources that Nepal's topology and climate provide. The Nepalese government's plan to develop 38,000 MW in 25 years (from 2010) supports this.

Local knowledge, research and expertise are important for the further development of the Nepalese hydropower industry and in this regard, the Turbine Testing Laboratory (TTL) at Kathmandu University (KU) will be highly useful. The International Standard *IEC60193* [1] contains rules and methods for model acceptance tests to be performed on hydraulic turbines, in order to ascertain the hydraulic performance of the model. As a guarantee of Francis turbine efficiency measurements performed at TTL, the laboratory is to be equipped with measuring instruments in accordance with *IEC60193* [1]. In TTL's feasibility study for a turbine manufacturing and testing facility in Nepal it is concluded that "…addition of test rigs at TTL as per the IEC standards and further development of human resources for R&D of hydro turbines is essential for developing TTL as the knowledge centre to support turbine manufacturing in Nepal." [3]. The Francis turbine test rig at NTNU's Waterpower Laboratory (VKL) can perform tests consistent with *IEC60193* [1], and the experiences from this setup has high utilitarian value for the design of the Francis rig at TTL.

## 2. Instrumentation

The instrumentation of the Francis turbine test rig at TTL is based upon the requirements as stated in *IEC60193* [1], and the experiences from the corresponding test rig at the Waterpower Laboratory, NTNU.

The piping and instrumentation diagram in Fig. 1 shows the suggested principal design of the system for the efficiency measurement of Francis turbines in the Turbine Testing Lab at Kathmandu University. Direction of flow and valves in open state as indicated by red line color provide one example from several possible running setups.

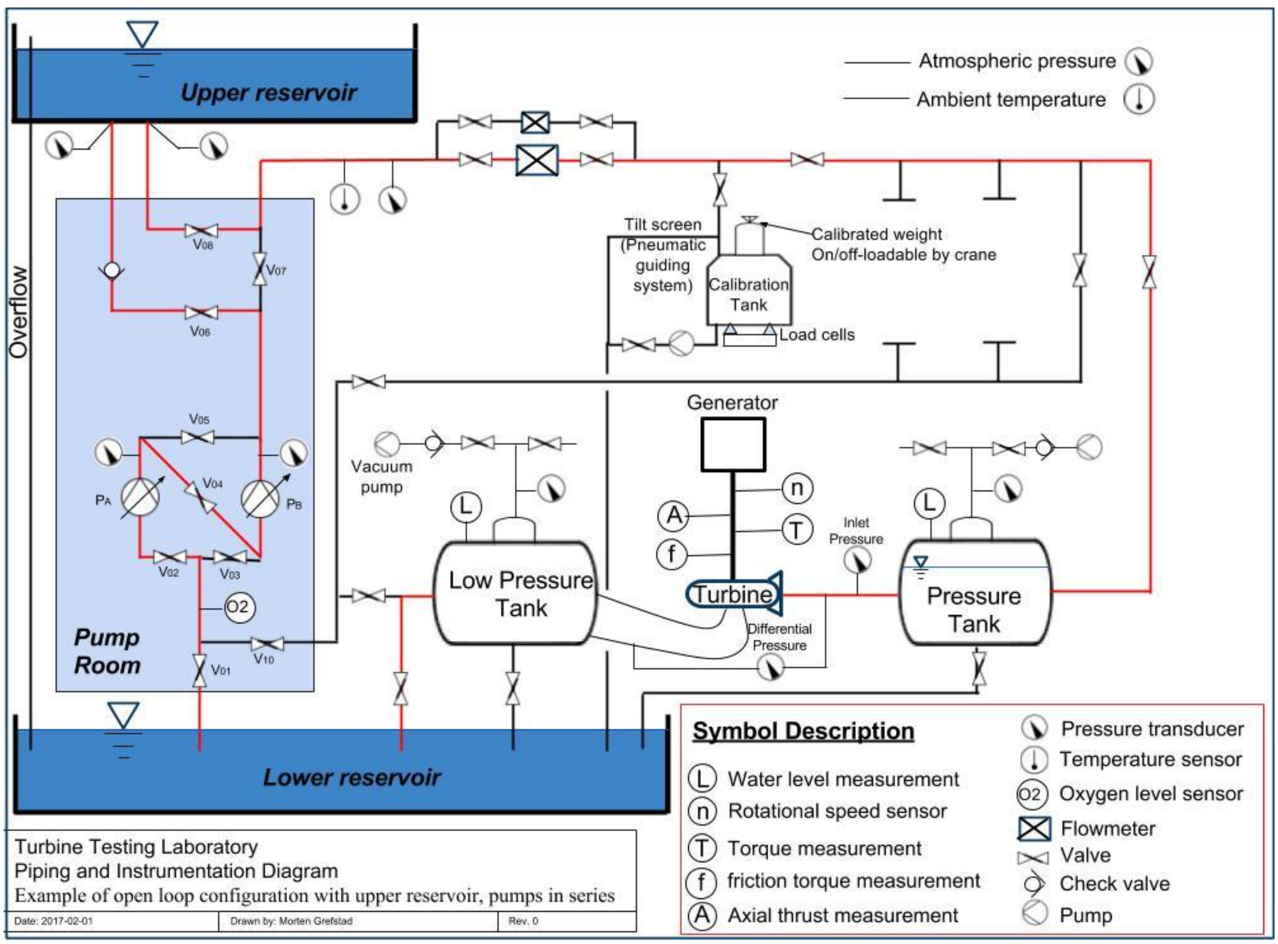


**Figure 1.** Example of Open Loop Configuration with both Reservoirs, Pumps in Series

Differential pressure transducers that are calibrated by a deadweight manometer measure the differential pressure between the turbine inlet and outlet. A digital barometer measures the atmospheric pressure. The water temperature is measured by a temperature probe and the dissolved oxygen level by an oxygen probe.

In conjunction with the main shaft are arrangements for measuring the generator- and friction torque, axial thrust and rotational speed. A hydraulic bearing and load cells measure the shaft torque, a primary method calibrated by weighing masses on a lever system. Strain gauges measuring the deflection of connecting parts between the axial bearing and the housing provide the base for calculation of the axial thrust. The strain gauges is a secondary method calibrated by applying an external force, i.e. calibrated weights. An electric counter and time base counting the pulses generated by the turbine shaft give the rotational speed.

An electromagnetic flowmeter calibrated by the weighing method measures the volume flow rate. The accuracy of the flowmeter is dependent on steady flow conditions and the velocity of flow. Flow velocity through the flowmeter is increased and made steadier by a converging pipe section upstream of the flowmeter and a diverging pipe section downstream. In addition, a cascade bend and a flow straightener upstream of the flowmeter contribute towards steadying the flow. Fig. 2 shows this setup with the calibration facility.

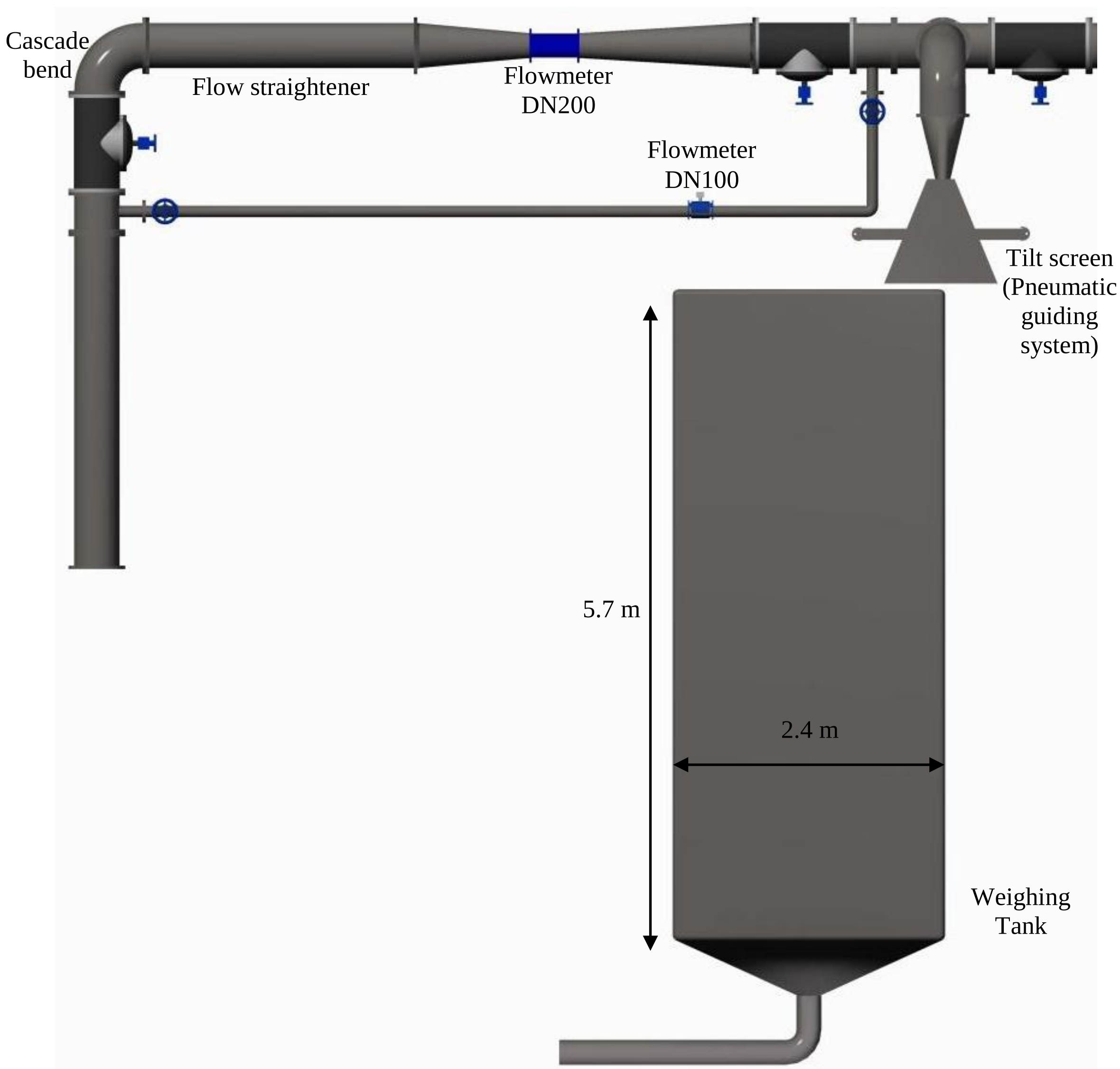


**Figure 2.** Flowmeter Setup at TTL

The components in connection with the Francis rig at TTL are shown in various combined views in Fig. 3 and Fig. 4.

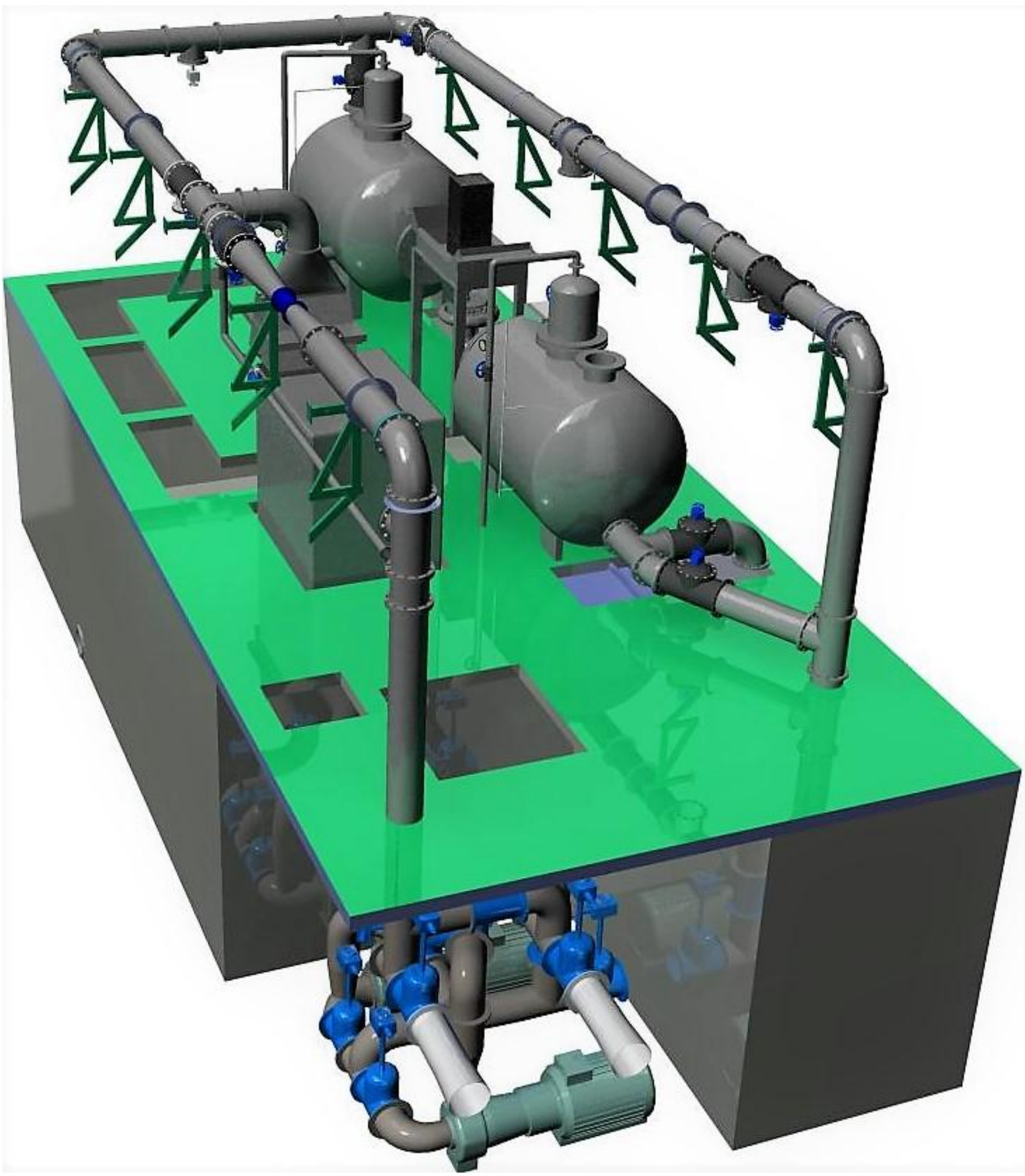

**Figure 3.** TTL Overview in 3D

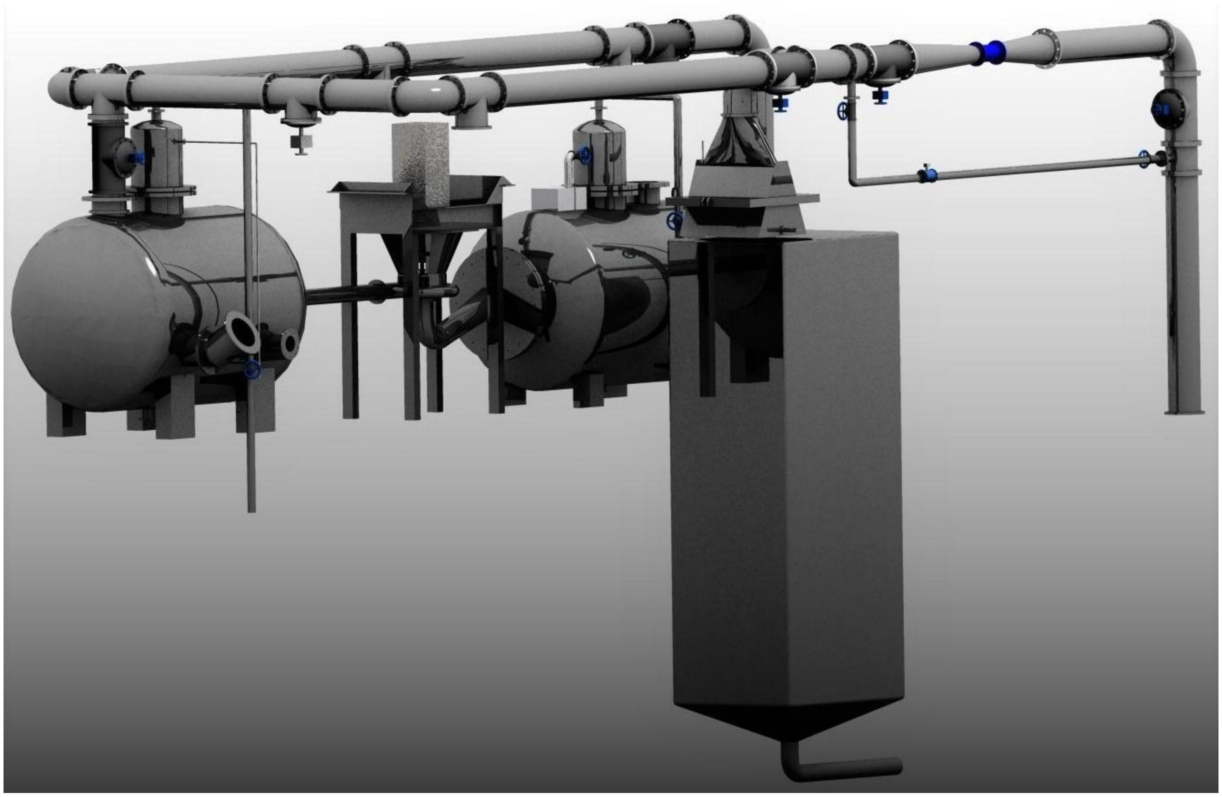

**Figure 4.** TTL Overview in 3D; Without Lab Building

## 3. Discussion

For discharge measurement, highest accuracy requires steady flow through the flowmeter. Achieving this normally requires the pipe upstream of the flowmeter to be longer than 10 times the diameter, and the downstream pipe to be 2 times the diameter. The piping arrangement at TTL makes it difficult to accomplish optimal flow conditions through the flowmeter, and adjustments to the pipe loop should be considered.

The flowmeter is calibrated by the weighing tank system utilizing substitution of a calibrated deadweight. For this reason, there must be space available to load the deadweight on and off the top of the weighing tank by the means of the crane installed at TTL. An attempt to make room for this is made in the design, but this has to be coordinated further taking the tilt screen and the shape of the calibrated weight to be substituted into consideration. Water can be guided to the weighing tank via a pipe detour just downstream of the flowmeters, but the illustrated solution in Fig. 2 may lack space for all necessary valves and equipment. Dependent of the laboratory space, options for placing the detour further downstream should be considered if the suggested flowmeter configuration is maintained. Based on a tank that may be used for the whole range of operational modes of the pump ($Q_{max}$=0.5$m^3$/s and minimum filling time $\Delta T_{min}$=30s), a minimum tank volume $V_{min}$=15$m^3$ is needed. The suggested tank design with volume $V \cong 24m^3$ is well within the limit, which means there is room for adjustments to the tank.

Great care should be taken when setting up the instrument for pressure measurement at TTL. Pressure taps are connected to a manifold leading into the differential pressure transducer. Avoiding the trapping of air must be considered when installing the tap piping, and transparent plastic pipes for high pressure is recommended so that air bubbles may be detected. No leaks are permitted in the pressure taps and pipes.

## 4. Conclusion

The Turbine Testing Laboratory (TTL) at Kathmandu University (KU) has been developed with the purpose of aiding in future developments and improvements of hydraulic machinery necessary for the Nepali market and throughout the Himalaya region. A major step towards this goal is the establishment of a Francis turbine test rig in accordance with the international standard *IEC60193* [1].

A system for the efficiency measurement of Francis turbines in TTL at KU has been designed, summarized in the piping and instrumentation diagram shown in Fig. 1.

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