Prediction of Turbine Needed For Future Hydropower Projects In Nepal

Subash Panta, Manish Lamsal, Bhola Thapa, Biraj Singh Thapa

Subash Pant

Manish Lamsal

Bhola Thapa

Biraj Singh Thapa

Abstract : As Nepal holds significant potential for a prosperous future market in hydropower and associated business developments, the Turbine Testing Lab (TTL) at Kathmandu University, Nepal has carried out a project that focuses on scientific studies to identify optimal turbine requirements for various hydropower projects. We collected and analyzed basic design data available from different sources to identify the turbine design specifications for the upcoming hydropower projects. As a result, we developed a computer program as a tool to support this work.

Findings from the current studies have shown that up to 60% of the 13000 MW capacity hydropower projects under survey stage in Nepal would need Francis type of turbine with unit size below 5 MW. This finding is also supportive to establish a basis for developing turbine manufacturing and maintenance competence in Nepal from business perspectives.

Key words: hydropower, turbine selection, Francis turbine, turbine manufacturing, Nepal

Nomenclature

Parameter	Symbol	Unit
Head	H	[m]
Discharge	Q	[m^3/sec]
Efficiency	η	-
Power	P	[W]
Specific speed	Ns	[rpm]
Angular velocity	ω	[radian/sec]
Specific angular velocity	ω	-
Specific Discharge	Q	-
Speed Number	Ω	-

Introduction

The demand for electrical energy in Nepal will reach 3,600 MW by the year 2027. It is expected that demand for electricity in India will reach to 1000 GW by 2030. Other countries in the South Asian region have similar forecasts. This surge in demand in the local and regional markets has boosted the construction of new power plants and called for the renovation of old ones for better efficiency (TTL 2013).

Kathmandu University, Nepal has developed the Turbine Testing Lab (TTL), with assistance from NORAD, NTNU and Nepalese industries. The main aim of TTL is to serve as a center of excellence to promote hydropower development in Nepal with technical solutions and motivational support to different stakeholders involved in this enterprise. Within the first year of its establishment, TTL has been able to generate collaborative momentum for holistic growth of hydropower development in Nepal. Technical competence in design and testing of hydro turbines with prospects of manufacturing them in Nepal is the most significant achievement of TTL so far (Thapa BS et al 2012).

Identification of optimal turbine type for the appropriate project can help the turbine manufacturing industries to plan their manufacturing capacity. For this purpose, a proper methodology should be adopted when selecting turbines for a hydropower project. The turbine selection process comes down mainly to two important parameters: seasonal discharge at the site and the height of standing water (referred to as "head"). Other deciding factors include how deep the turbine must be set, efficiency, and cost. To optimize these factors, a proper technical survey on turbine selection should be carried out to collect relevant data, mathematical calculation and analyses on it. Looking at the potential growth of hydropower in Nepal in years to come, we intend to serve manufacturing companies who plan to initiate the production of turbines for hydropower in the country.

Research Methodology

This study analyzes the turbine specifications in all hydropower around the country. For this research, information was collected on 540 different hydropower projects with a potential combined capacity 16,000 MW. The nature of these projects is summarized Figure 1.

This research provides a layout of how the turbine specifications are distributed in all hydropower projects around the country. The majority of projects, it should be noted, are under the planning or survey stage.

The methodology adopted for proper selection and prediction of turbine and its working condition consisted of calculative and research approaches. All the calculations were performed using the program "Hydraulic Turbine Selection" and Excel programs. The course of action we adopted to produce the final result is shown in Figure 2.

Data collection

Relevant data from hydropower projects already built and those under construction around the country have been collected from various sources such as the Department of Electricity Development (DoED) and Environmental Resources Group (eRG) websites, and past research on siamilar topics done in the TTL (DoED 2012; eRG 2012;

TTL 2013). The data were then tabulated in an Excel worksheet to analyze their common specifications and represent them in graphical forms.

We used data on head and discharge and ran them under different combination of rotational speeds and number of units to get the optimum turbine design conditions. This work required frequent alteration of the calculations. We employed a software program called "Hydraulic Turbine Selection" to aid the calculation works. The program allowed us to provide inputs as required and the program provided details regarding turbine specifications. Segregation of the data is then done with an elimination process that aims to bring the results (specifically speed number) to a more common platform.

During the course of the research, the program was run only on three standard RPM speeds (600, 900 and 1500) to provide a range of speed under which an actual project may run; this accuracy, however, may be debated. Our aim was to link the turbine specifications on a much closer basis.

Software Development

Optimum selection of a turbine for a hydroelectric power plant for a specific site requires a careful evaluation of turbine technology. Generally, a Hill chart diagram has been used to predict the selection of turbine for a hydropower project. However, during the course of our research, speed numbers were used to forecast the type of turbine to be employed. The program operates on basic turbo machinery principles.

The Hydraulic Turbine selection computer program[1] is an evaluation tool that aids hydro project developers in the work of choosing the best combination of turbine. The program brings together the necessary analytical tools, up-to-date technical information, and data to enable the user to develop a preliminary design and select the proper turbine for a hydro power site.

There are different hydro turbines available, ranging from horizontal axis very-low-head mini-bulb units to large high-head impulse units. For example, for potential sites with low to medium combinations of flow (5 to 320 cubic meters per second) and head (3 to 444 meters), a list of turbine choices are available. Narrowing the specifications still results in several options. Because of the large number of available turbine types, selecting the optimum turbine for a particular site can be a difficult process. Furthermore, the selection of turbine can also depend on other factors such as efficiency, cost, and set up. However, these factors were not considered during the course of research.

The program requires the user to enter four parameters describing the turbine requirements. These parameters were either known from the site conditions or chosen by the program user (such as Head, Discharge, RPM, and Number of units). These four inputs provide adequate information for initial turbine selection. The parameters and data entered for illustrative purposes then calculate following parameters:

- Turbine type according to speed number
- Turbine type according to specific speed
- Speed number
- Specific speed
- Power

Mathematical Relations and Criteria

Selection of the hydraulic turbine for a particular site depends on different factors. Various calculations are required during the selection process. The main parameter selected to choose the turbine in this research is the speed number. The following formulas are required to calculate the speed number when given certain parameters. The program runs on the following basic hydraulic turbine selection formulas:

Data: Head (H in m), Discharge (Q in m^3/sec), Revolutions per minute (N in rpm), Number of units of turbine.

Assuming efficiency one for general study,

Power $P = \eta * g * Q * H$

Specific Speed, $N\_s = (N\sqrt{P})/H^{(5/4)}$

Angular Velocity, $\omega = (2*\pi*N)/60$

Specific Angular Velocity, $\underline{\omega} = \omega/\sqrt{(2*g*H)}$

Specific Discharge, $\underline{Q} = \frac{Q}{\sqrt{2*g*H}}$

Speed Number, $\underline{\Omega} = \underline{\omega}\sqrt{(\underline{Q})}$

The speed number is a parameter for classification of the turbines. This means that the different types of turbines group themselves in certain ranges of speed numbers (Kjølle et al 2001). After calculating the speed number, the turbines are separated on the basis of those speed numbers.

The ordinary turbines cover ranges as specifically stated on a speed number category below (Kjølle et al 2001).

To assist the user in selecting proper turbine type, various alterations in RPM and number of units can be done in the program in order to select the proper turbine. The idea to view turbine selection in different hydropower contexts resulted from this approach (by changing the RPM and Number of units frequently) and

$\underline{\Omega} < 0.2 \rightarrow$ "PELTON TURBINE"

$0.2 < \underline{\Omega} < 1 \rightarrow$ "FRANCISTURBINE"

$\underline{\Omega} > 1 \rightarrow$ "KAPLANTURBINE"

selecting the proper turbine in the context of Nepal.

Results and Discussions

Turbine type distribution

The initial distribution charts have been developed mainly on the basis of the type of turbine used in hydropower. The results were obtained separately for hydropower already constructed, those planned and those proposed as shown in Figure 4, 5 and 6 respectively.

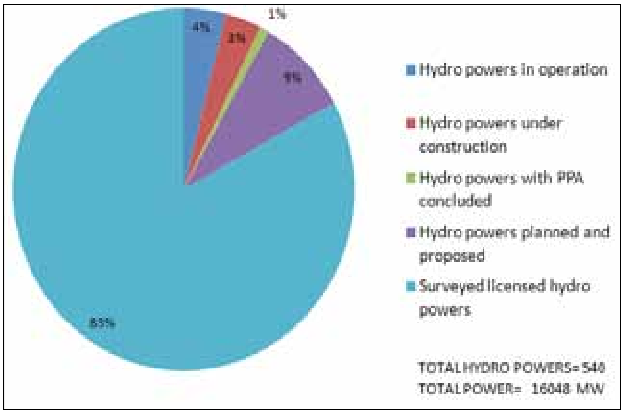

Figure 1. Scenario of Hydro power in Nepal

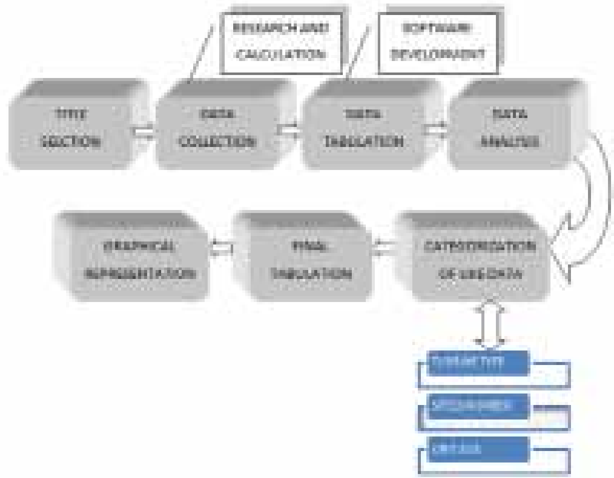

Figure 2. Methodology of the research work

The findings showed that almost 75% of the hydropower uses or will use Francis turbines for power generation. This illustrates that the turbine market is dominated by Francis and thus should give investors notice on this turbine category. So the next development of distribution chart is focused on hydro powers that use the Francis type of turbine. Now we consider what type of Francis turbine is most commonly used.

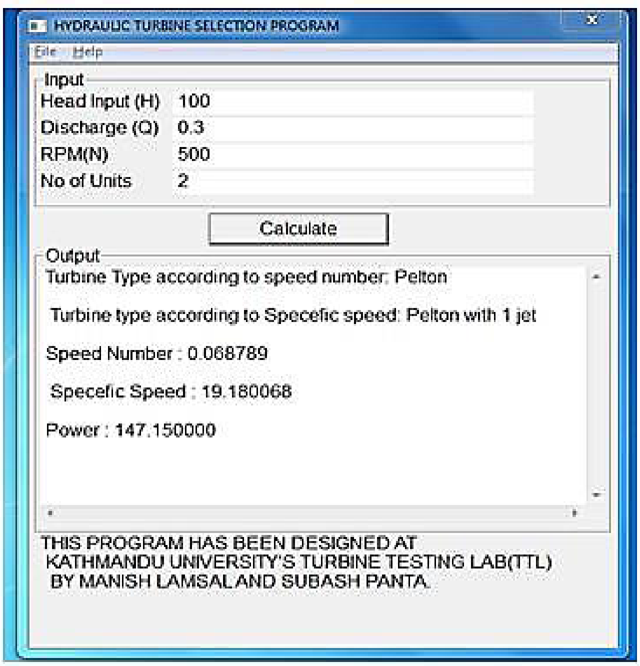

Figure 3. Hydraulic Turbine Selection Program

Speed number distribution

Hydropower under construction using Francis turbine are then taken into special consideration. They are further classified according to their speed number as Low, Medium to Low, Medium to High, and High head Francis turbine. The results obtained showed that high head Francis turbines with speed numbers in the range of

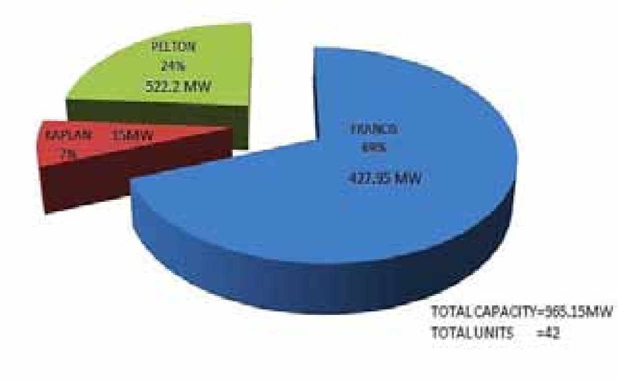

Figure 4.Turbine type distribution in major hydropowers.

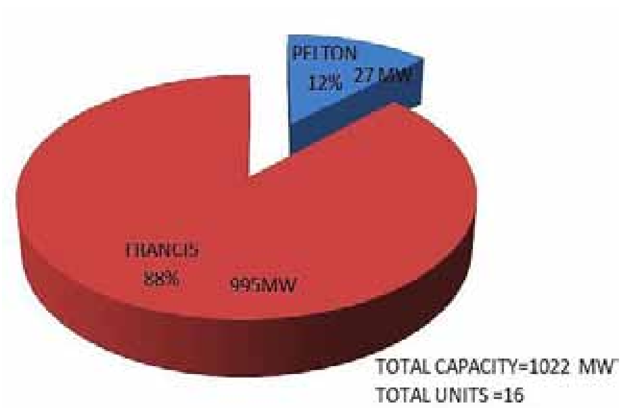

Figure 5. Turbine type distribution in planned and proposed hydropowers.

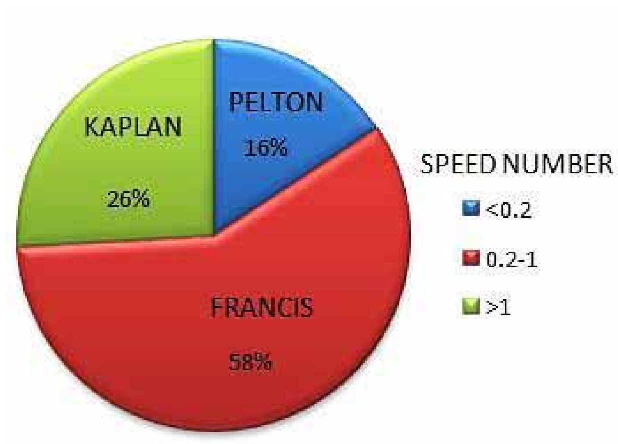

Figure 6. Turbine type distribution in hydropowers under construction.

0.2 - 0.3 are most commonly used Nepalese hydropower.

Type Of Francis Turbine	Speed Number	Power (MW)
Low Head Francis Turbine	0.7-1.0	43.5
Medium To Low Head Francis Turbine	0.5-0.7	76.86
Medium To High Head Francis Turbine	0.3-0.4	156.3
High Head Francis Turbine	0.2-0.3	211.4
Total		488.06

Table 1. Type of Francis turbine along with their speed numbers

Figure 7 below shows that 43% of the hydropower under construction use high head Francis turbine for operation.

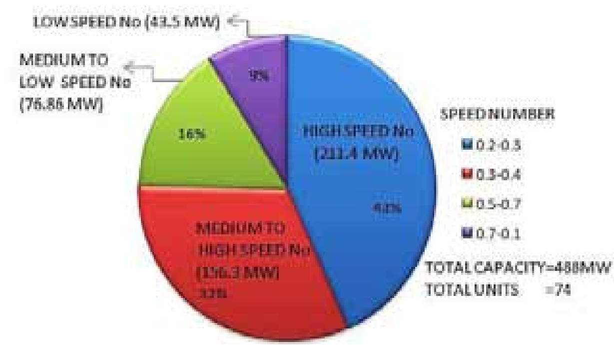

Figure 7. Speed number distribution in hydropowers under construction

Unit size distribution

In Nepal alone, 12 projects with collective 90.7 MW capacities are under construction; Construction licenses have been awarded to 43 new projects with 225.2 MW capacity. Survey licenses have been awarded to 515 new projects with 13,353 MW capacity, and 2,188 applications for survey licenses for new projects totaling 30,353 MW have been received at DoED (TTL et al 2013). In Nepal, more than 50% of turbines needed for the power plants under construction fall under unit size of 1-5 MW. More than 80% of turbines for the projects currently under survey falls under 25 MW of unit size.

The shaping of the turbine industry, to a great extent, depends on the size of the units that the manufacturing industry is required to produce. Determining in advance the sizes needed would assist in ensuring proper growth of the business and hydropower in general. The industries then can develop their infrastructures based on the demand in the context of Nepal. As shown in Figure 8, turbine sizes ranging from 0.25-5 MW are the most needed in the hydropower projects surveyed so far. Around 60% of the hydro turbines to be used in the surveyed hydro powers fall into this category. Manufacturing industries, therefore, can specially consider these sizes when planning the capacity of their turbine production. At present, Nepal has sufficient technology to design and manufacture Francis turbines in Nepal up to 5 MW unit size. However, expansion can be done for upcoming projects with Francis turbines up to 25 MW unit size.

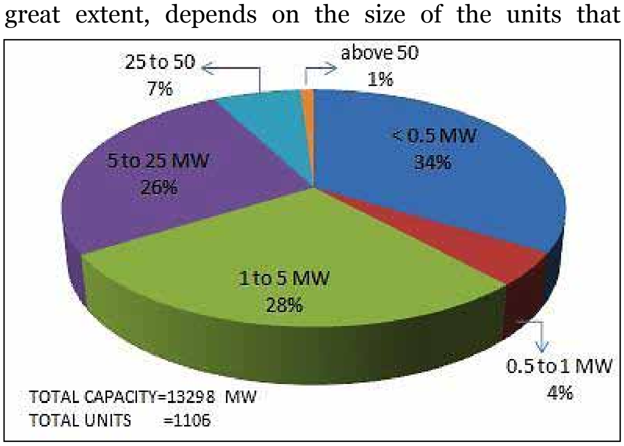

Figure 8. Unit size distribution in surveyed hydropower projects

Possibility of Turbine Manufacturing in Nepal

The huge hydropower potential in Nepal along with the growing interest of many investors in this sector is a morale booster for the establishment of turbine industries. Manufacturing process is an enormous portion that will encourage massive investment. Turbine manufacturing thus is likely to cover a huge market in the days to come. The Turbine Testing Lab (TTL) at Kathmandu University (KU) has foreseen a feasible prospect of setting up a Francis turbine manufacturing facility in Nepal. It has been conducting a feasibility study to identify the market and product for viable and sustainable business of the turbine manufacturing facility. The project helps in proper streamlining of the turbine market leading towards the prosperous growth of the manufacturing industry. The ultimate goal of the project is to aid and organize the process of turbine manufacturing in Nepal.

Conclusion

The prospect of hydropower development in Nepal is huge. Massive opportunities in hydropower field lay ahead in years to come. This sets the background for industrial growth in the turbine manufacturing sector as well. Turbine manufacturing market is an aspect if taken into appropriate consideration can bring country's economic prosperity. Proper planning to determine the status of market before initiation of any manufacturing industry is necessary.

The paper generally condenses some of the specifics of turbine choice in Nepal and supports proper initiation for those who aim to inaugurate themselves into the manufacturing aspect in the hydropower field.

— —

Subash Panta *is a final year undergraduate student in Mechanical Engineering, Department at Kathmandu University (K.U). He is involved in several project activities at TTL.*

Continued in page 40

to examine to what extent these design principles can be used so that more cost effective, safe and long-term sustainable underground high pressure tunnels and shafts as waterway systems are practiced in the Himalaya.

- -

Krishna Kanta Panthi, *PhD, is an Associate Professor in Geological Engineering in the Department of Geology and Mineral Resources Engineering, Norwegian University and Science and Technology (NTNU), Trondheim, Norway. He has completed his Dr. Ing. degree on the 'Analysis of Engineering Uncertainties Related to Tunneling in the Himalayan Rock Mass Conditions' in 2006 from NTNU. He completed his M.Sc. in Hydropower Development in 1998 and M.Sc. in Civil Engineering in 1992. He is the author of many scientific papers related to tunneling, rock slope engineering and hydropower. He has over 15 years of experience in the design, construction and planning of tunneling and hydropower projects in the Himalaya (Nepal and India).*
Corresponding address: krishna.panthi@ntnu.no

References

Hveding V. 1992. Hydropower development in Norway. Hydropower Development, series no. 1. Department of Hydraulic Engineering, Norwegian Institute of Technology, p.83.

Nilsen B. and Thidemann A. 1992. Rock Engineering. Hydropower Development, series no. 9. Department of Hydraulic Engineering, Norwegian Institute of Technology, p.156.

Naturhistoriska Riksmuseet (NRM). 2013. http://www.nrm.se/english (viewed on 10.12.2013).

Palmstrom A. 1989. Geology of Norway. Norwegian Soil and Rock Engineering Association, publication no. 6.

Palmstrom A. 1996. Engineering geology and rock engineering applied in the design of Norwegian tunnels. Proceedings: Tunnels for the third Millennium, 16p.

Panthi K. K. 2012. Evaluation of rock bursting phenomena in a tunnel in the Himalaya. Bulletin of Engineering Geology and the Environment, Vol. 71, pp. 761 - 769.

Panthi K. K. 2013. Collapse and burst debris flood at Svandalflona. Norwegian Tunneling Society, Publication 12, pp. 117 – 123.

Statistics Norway (SSB). 2011. www.ssb.no/en (viewed on 11.12.2013).

Continued From page 26

Corresponding address: subash_life@hotmail.com

Manish Lamsal *is a final year undergraduate student in Mechanical Engineering Department at KU. He is involved in several project activities at TTL.*
Corresponding address: lamsalmanish90@gmail.com

Bhola Thapa *is a supervisor for this study. He is a professor in Mechanical Engineering Department and also Registrar at KU. He obtained his PhD in Mechanical Engineering at the Norwegian University of Science and Technology in (NTNU) 2004. His research area is Sand Erosion of Hydraulic Machinery.*
Corresponding address: bhola@ku.edu.np

Biraj Singh Thapa *is a co-supervisor for this study. He has also worked as Faculty In-charge of Turbine Testing Lab in Mechanical Engineering Department at Kathmandu University. He holds MS Research Degree in Design of Francis turbines. He has been involved in several R&D and professional projects to design and develop Francis turbines. Currently, he is doing his PhD at NTNU.*
Corresponding address: biraj.s.thapa@ntnu.no

All the authours are associated with Turbine Testing Lab, School of Engineering, K. U, Nepal.

References

Brekke H, 2010, State of the art in turbine design, Water power laboratory, NTNU publications, Trondheim, Norway.

Department of Electricity Development (DoED), 2012, Applications for Survey License (Below 1 MW). URL:http://www.doed.gov.np/application-survey_license_for_generation_below-1mw.php

Environmental Resources Group Ltd (ERG)., 2012, Hydropower. URL: http://www.erg.com.np/hydropower_national.php

Erichsen HP, 2011, Mechanical design of Francis turbine exposed to sediment erosion, Waterpower Laboratory, NTNU publications, Trondheim, Norway.

Kjølle A, 2001, Hydropower in Norway: Mechanical Equipment, in *Proceedings of the IAHR Congress*, Trondheim, Norway.

Turbine Testing Lab (TTL), 2013, Feasibility Study for Turbine Manufacturing and Testing Facility in Nepal, Technical Report submitted to NORAD. URL: http://ku.edu.np/ttl/index.php/rresearch?id=86

Thapa BS, Thapa B, Dahlhaug OG, 2012, Current research in hydraulic turbines for handling sediments. Energy 47, Issue 1, pp. 62-69.

Wei Z, Finstad PH, Olimstad G, Walseth E, Eltvik M, 2009, High Pressure Hydraulic Machinery, PhD Thesis, Water power Laboratory, Norwegian Institute of Science and Technology.

Foot Note:

1. The Hydraulic Turbine selection computer program runs at an interface created by the codes generated in C++ programming language.