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Francis Turbine : Manufacturing in the context of Nepal

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Abstract

Developing a sustainable way of designing and manufacturing hydro turbines is a major goal of every turbine industry. Due to the wide range of application and higher efficiency rate, Francis turbine stays apart from all other turbines and is most preferred around the globe. Continuous research and development of Francis turbine are carried out by a huge number of researchers and a group of engineers. Talking about the turbine development in the underdeveloped country like Nepal, the country has also taken some major steps for designing and manufacturing Francis turbine within the country. EnergizeNepal Project has also encouraged human resources to carry out the research for the development of renewable energy in Nepal. Every development gives birth to the new challenges that need to be overcome. The paper presents the inventions, discuss and review the possible way to design and manufacture the Francis turbine for small hydropower projects within Nepal. The study focuses on the design, manufacturing and analysis of Francis turbine. Different conventional and modern way of manufacturing turbines are studied.

Keywords: Francis Turbine, Sediment Erosion, Manufacturing

1. Intoduction

Hydropower is the largest contributor among all renewable energy sources. It refers to the conversion of flowing water into sustainable electrical energy. [1] There has been continuous development in hydropower plant since it was first introduced. The modern development in the turbines and generator can generate electricity from very small to the very large scale. Hydro power plants can be categorised into three sizes: large (>30 MW), small (100 kW-30 MW) and micro (<100 kW).

According to the electricity demand forecast done by the Government of Nepal, the energy demand will reach up to 15,000 MW by 2030 and 35,000 MW by 2040. With some better

policy if the GDP growth is increased by doubled, then the demand will reach up to 18,000 MW by 2025 and 50,000 MW by 2040. [2] More than 70% of the hydropower uses or will be using Francis turbine. 69% of the major hydropower under operation and 58% of the hydropower under construction in Nepal uses Francis turbine for power generation. [3] This clearly defines the importance of manufacturing Francis turbine within the country.

1.1 Problem Statement

Design enhancement and development of the sustainable manufacturing process of hydro turbines has been a new trend in the hydropower industry nowadays. The new concept of optimization seems to be promising because of a combined application of Computer-Aided Design (CAD), Computer-Aided Manufacturing (CAM), Computer Numerical Control (CNC) and various simulation software. There is numerous research that are going on a huge scale in developed countries and they have got some promising results. But if we consider the underdeveloped and developing countries, importing these new concepts has been always very expensive. The technical and maintenance issue after the import is also not that economic. To overcome these kinds of issues in underdeveloped and developing countries various project is funded by the national level or by the private sector to develop small size hydropower plants, which can be produced with locally available resources and simplified process.

Even though various research is conducted among local and national level within the developing countries there still remains some major issues to be solved regarding the standard, durability, and efficiency which raise the question: ***" Which level of optimization is affordable and acceptable by the existing infrastructure they have till date?***

1.2 Objective

The objective of this research is to study the possibility of designing and manufacturing Francis turbines within Nepal. Due to the high sediment-laden condition of the river in Nepal, the country needs to figure out the possible solution to overcome the damage within the runner. The existing manufacturing techniques and methodology within the country may not meet the complex profile of the runner blade which is a big challenge among the Nepali manufactures. So, finding an alternative design and manufacturing techniques will create a milestone for future hydropower projects in Nepal.

2. State of Art

Francis turbine developed by James B. Francis, are the most common water turbines that are being used in most of the hydro power stations. The higher efficiency rate and wide range of application make Francis turbine most preferred turbines in hydro power stations around the globe. [4] In Nepal, Francis turbine was first installed in Panauti Hydropower Station, which was the third hydro station in the country commissioned in the year 1965 with total production capacity of 2.4 MW. The hydropower consists of three Francis turbines with the individual capacity of 0.8 MW. After two successive year in 1967, Trishuli Hydropower station was commissioned with the capacity of 21 MW consisting seven Francis turbines with capacity of 3 MW each. Since then most of the hydro plants in Nepal are installed with Francis Turbines for the power generation.

Due to wide range of domain covered by the Francis turbine it is preferred by small to large power plants. It can operate for heads from 3 to 400 meters. [5] One of the largest hydropower in the world, the Three Gorges Dam of China has installed capacity of producing 18,200 MW with 22 sets of Francis turbine with the capacity 700 MW each. [6] There has been continuous development to improve the efficiency and quality of the Francis turbines, since it has the highest percentile distribution in every continent. The traditional way of designing depends upon the experiments, measurements and model testing which is not enough in this modern era to verify if the turbines are efficient enough. Different sophisticated technique is developed with high engineering efforts to design and manufacture each component. To verify the design, various flow simulation software or CFD (Computational fluid dynamics) are being used. The simulation software are proven to be cost effective and an accurate alternative to test the model. [7]

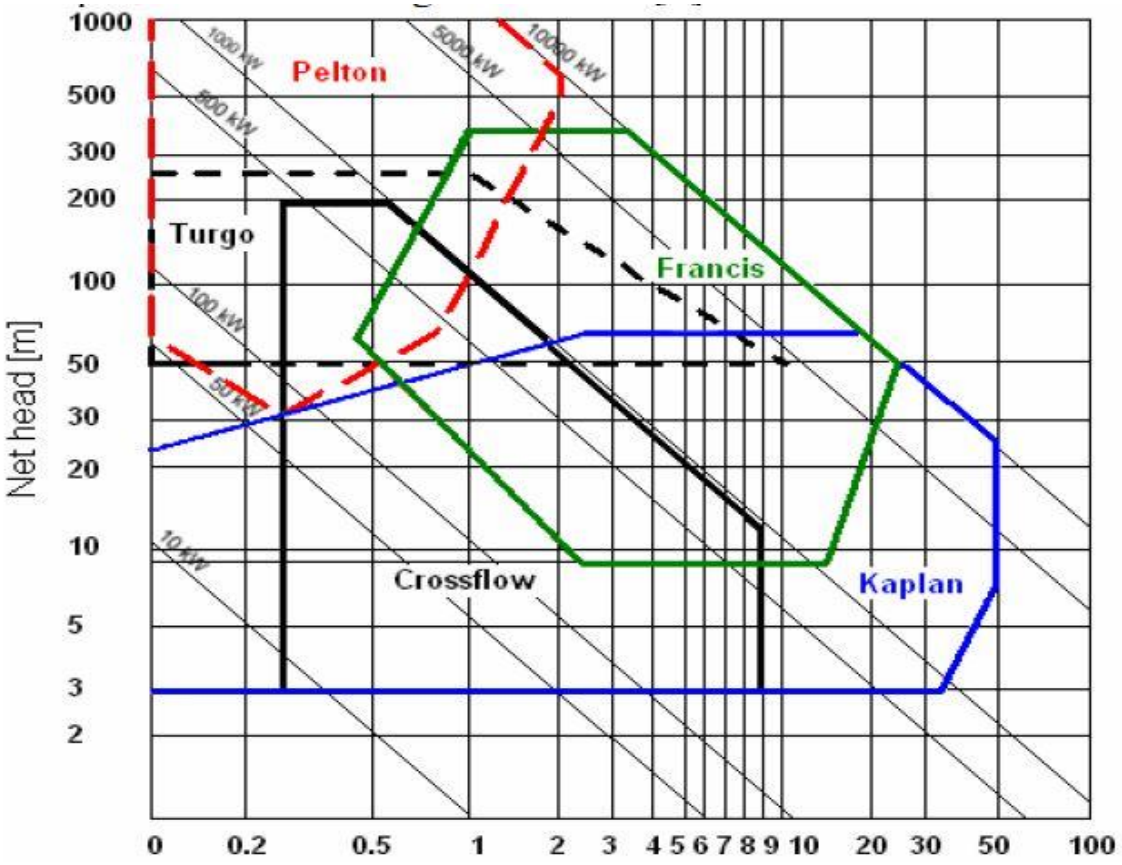

Figure 1: Turbine application range chart for different turbines

Source: [5]

Hydropower is becoming well developed and costs competitive renewable energy technology. After various tests, the turbines are designed to run at designed operation points. Since the turbine are responding fast, they are often forced to operate under off-design conditions which leads to unwanted loss and reduced efficiency. To overcome these kinds of unwanted forced operations only design improvement may not be enough and modernization of hydropower stations must be considered. [8] Among different renewable energy resources like wind power and solar power, small-scale hydropower can offer a longer lifetime. The infrastructure (dams) is applicable for different uses like irrigation, factories, recreational purpose, city water and many more. Unlike the mega projects, small hydropower always focuses on low-initial cost, high profitability, and low labour costs. To meet these kinds of conditions only design optimization is not a better idea. To achieve the required efficiency, optimization is done in the operation mode and digital controls.[9]

The geographical location of the country is also responsible to introduce different new problems in the overall design of the hydropower stations. The hydropower industry across Asia and South America are facing the problem of sediment erosion. The presence of a high

concentration of hard particles in the river of the Asian and South American subcontinent leads to the severe effects on hydro turbines. These often lead to the unwanted shut down of the power plants during the monsoon season. The research is being carried by various researchers and a group of engineers and they have some promising solutions for designing the turbine to reduce the sediment erosion. Introducing sediment erosion as one of the design parameters of Francis turbine can be a suitable solution to overcome the problem.[10]

Hydropower is also a major factor in economic and social development at a local, national and regional level. The availability of a large volume of water combined with steep slopes offers more than 83,000 MW of electricity in Nepal. [11] The potential to share cross border supply can surely help for the economic growth of the nation. But in an underdeveloped country like Nepal due to the lack of enough budget, funding is done by neighbouring countries and they receive a greater share of energy generated. If the country can come up with better plans and proposal for the hydropower development, these projects surely help in moving from being a "land-locked" country to a "land-linked" country. [12]

3. Methods and Technology

The overall design and manufacturing of the Francis turbine are being carried out in various steps to get the better efficiency and durability. During dimensioning, Francis turbine can be divided mechanical and hydraulic parts. Each individual parts of the turbine are precisely dimensioned and designed and are later analysed by using various computational software. [13] The reason behind using computational software for the analysis is due to the complex profile of the blades and complete runner. [14] The turbine is a movable part with the structures that are deformable. To achieve the better results, FSI analysis is carried out. FSI analysis is done by doing flow simulations in the moveable parts (blades) and the results obtained are later exported for the further structural analysis in FEM. [15] The structural analysis will not affect the CFD analysis and hence the overall analysis is unidirectional. The complicated geometry demands high computer memory and CPU time. [16] Among all the components of Francis turbine, the design parameter and hydraulic performance of the turbine are affected by the design parameter of the runner. Due to the complex geometry of the runner, design and manufacturing methods for the runner has high constraints and requirement. Nevertheless, design and optimization of each individual component is crucial. [17]

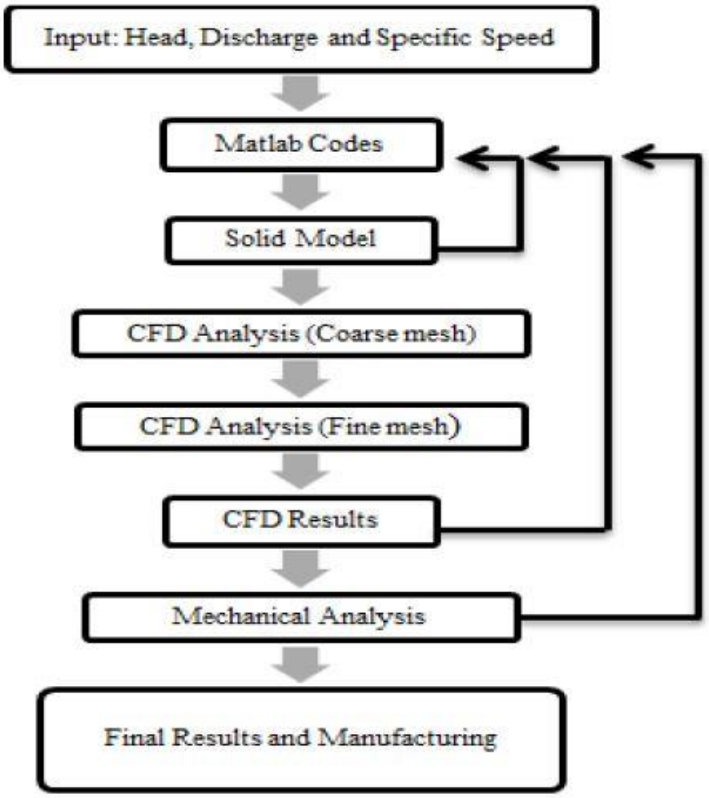

Figure 2:Runner design methodology

Source : [17]

More than 65% of the hydropower in Nepal are installed with Francis turbine. Due to the lack of the resources, modern tools and techniques the complete design and manufacturing of the turbine is not achieved by the country so far. But several attempts have been made with the collaboration of the Government of Nepal, Nepal Hydro Electric, Turbine Testing Lab, Kathmandu University. Modern manufacturing techniques like CNC machining that are practised world-wide for the manufacturing of the complex profile of the turbine is not affordable by the county. The manufacturing process and techniques that are being practiced by Nepal for the manufacturing are the old manufacturing techniques that can be done with the available resources. Below we discuss some manufacturing methods practiced by the country for the manufacturing of the turbine blades.

3.1 Casting

Casting is an old manufacturing process used for manufacturing turbines. Casting of the turbine blades are done for centuries. Depending on the size, different manufacturing

techniques are applied for the production. Thicker turbine blades are preferred to be casted. [18] Due to the complex geometry and curvature of the turbine blades, investment casting is preferred for the manufacturing of the turbine blades. [19] Investment casting, also known as low wax casting, has tighter tolerances and allows the production of the small parts with high level of accuracy. The attempt of single piece casting using investment casting is attempted by Kathmandu University, Dhulikhel. The first attempt of casting of the runner was not successful. Later the defects are removed after studying the possible reason for the failure and finally single piece casting was done successfully. [20]

3.2 Pressing

Pressing is another manufacturing techniques widely used for manufacturing turbine blades. Pressed or hot-forged parts are relatively stronger than cast or machined metal parts. Therefore, this technique is widely used to produce parts with superior mechanical properties. [21] Nowadays cold pressing is mostly entertained by the manufactures to produce the blades. Due to the more strength and less manufacturing cost cold pressing is done to manufacture larger blades. Nevertheless, both techniques of pressing (hot and cold) are widely used for manufacturing turbine blades. [20]

4. Challenges

Despite of the higher potential of the hydropower in Nepal, lack of infrastructures like manufacturing industries and lack of proper guidance is slowing down the overall development process. Researchers and group of engineers are not supplied with required resources to conduct the research and experiment to verify if any new design can overcome the existing problems of hydropower. Even if the proposed design and experiments are verified, lack of in-house production of the different sophisticated parts of the turbines leads to importing of these parts with finally leads to huge investment costs. Nepali manufactures still depends on conventional manufacturing methods which cannot meet the engineered design of the turbines.

5. Summary

With the huge potential of hydropower generation, Nepal needs to take some serious major steps to meet the future energy demands of the country. The study shows that Nepal has a potential of manufacturing small size hydro turbines, which are very effective for the rural electrification. Different groups of motivated researchers and engineers have come up with different proposed design and experimental results to overcome the challenges that are arising

due to the geographical location of the country. With the collaborative effort of the Nepal Government and researchers its time to motivate Nepali turbine manufactures to step into manufacturing of Francis turbine within Nepal. It helps to identify the challenges that come along and it will always be a learning step to manufacture Francis turbine for larger application.

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