Design & Analysis of Single stage Hydraulic turbine

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***Abstract*: In this world of depleting resources, renewable energy plays an important role. Hydro energy is one of the major renewable energy sources. In this study Single Stage turbine is designed to extract energy from flowing water. A 3D model is designed and analyzed using Computational Fluid dynamics concepts in order to understand the feasibility of the Design. This is a single stage water turbine which is more efficient due to its reaction action of water on blades. To extract more energy and make turbine suitable for open channel flow with moderate velocity, the turbine blades are inclined to 30° with respect to Horizontal axis of the turbine wheel. From the analysis it was found that the hydraulic efficiency of the turbine is 64% when backflow of the water is neglected.**

***Keywords*- Fluid dynamics, water turbine, Analysis, efficiency, backflow.**

I. INTRODUCTION

In present era producing electrical energy without using fossil fuel is big challenge. In future there may be chances of lack of fossil fuels, so producing alternative energy resources is very important. Renewable energy such as hydro, wind, solar and tidal power is used to overcome such problems. Hydro energy is mainly used because of its availability and low cost. The extraction of hydro energy can be done using turbines. Single stage water turbine is mainly used for producing electric energy using water. It can produce energy continuously using flowing water. This project explained that, the main equipment in hydro power generation is turbine. There are many types of turbines present in the world, among them cross flow water turbine is popular, because it has many advantages like small head, small water flow rate, and simple structure simple manufacturing method. The objective of this paper is to, use of flowing water of flow channel in hydro power plant for generating power [1]. In this project hydro turbine converts kinetic energy in the form of flowing water to electrical energy by using turbine and generator. The aim of this project is to create an affordable and portable device to allow the capture of energy from a stream of flowing water in settings where no additional power source is available. The hydro turbine design is very small. This article provides information about hydro power technologies and water turbines, and also focuses on performance of hydropower system and gives idea about most suitable turbine which can be used [2,3,4]. This turbine has horizontal axis of rotation and can be equipped with step up gear drive and V belt drive to increase the turbine speed before it reaches the alternator. Alternator with minimum capacity of 1kW can be used to harness the hydro energy of the flowing water.

II. DESIGN OF SINGLE STAGE WATER TURBINE

The design is made in 2 stages, namely 2D & 3D using "SolidWorks 2022" which is a solid modeler which utilizes a parametric feature based approach. 2D model of turbine is as shown in figure 1. It consists of blades of dimension 0.3 x 0.8m and inclined at 30^o to horizontal axis. From the end of turbine shaft, the connection can be given to gearbox, and then to alternator using suitable coupling. There are equally spaced ten blades arranged on the ring such that $1/3^{rd}$ of the blade is inside the ring and $2/3^{rd}$ of the blade is outside. The test is conducted by immersing the blades in different proportions, so that the contact of water increases with the blades and power output is also increased. The Fig. 1 shows the 2D view of Single Stage Water Turbine. Four views such as front view, side view, top view, Isometric views are shown so that 2D model can give full details about the dimensions of various components of the turbine.

3D model of the turbine setup is as shown in the figure 2. It consists of water wheel & blades arrangement. The turbine shaft is coupled with gearbox shaft to transmit power. The alternator setup is placed above the water level. The gearbox shaft is coupled with alternator shaft. Alternator is connected to electric switches, using which it can possible to use electric power produced from the rotation of water turbine. Blades of the water wheel are made of Galvanized iron (G.I 16 gauge). Blades are rectangle in shape with size of 0.25 x 0.75m. Blades are inclined 30^0 & welded to the 10mm x 10mm rod which is curved as a ring. Ring diameter is 0.6m & Single Turbine wheel length is 1.73m. There are 2 turbine wheels arranged in series. Total length of the turbine wheel including the intermediate coupling is 4.103m &Total weight of turbine is estimated to be 200kg.
For producing the electric power from the actual turbine developed using this design, it is recommended to use an alternator is having the specification of 230V, 3-Phase, 300 RPM and 1kW. Alternator can be rigidly mounted on a table with the help of fasteners. Plummer block made of grey cast iron used for supporting the entire unit. Mechanical lifter can be used to adjust the height of the blade from contact of water.

The Design calculations were made for a moderate Velocity of flowing water of 1.5m/s. Tangential force of the blade was estimated to be 2445 N which is acting on the blade. Mass flow rate of water is found to be 480 kg/sec acting on the blade in the direction of flow. Pressure energy acting on the blade surface in the perpendicular direction is calculated and found as 1.17kW. Total useful hydraulic energy acting on each blade is estimated to be 1.23kW. Calculations are done based on mathematical formulae & velocity triangles corresponding to hydraulic turbines.

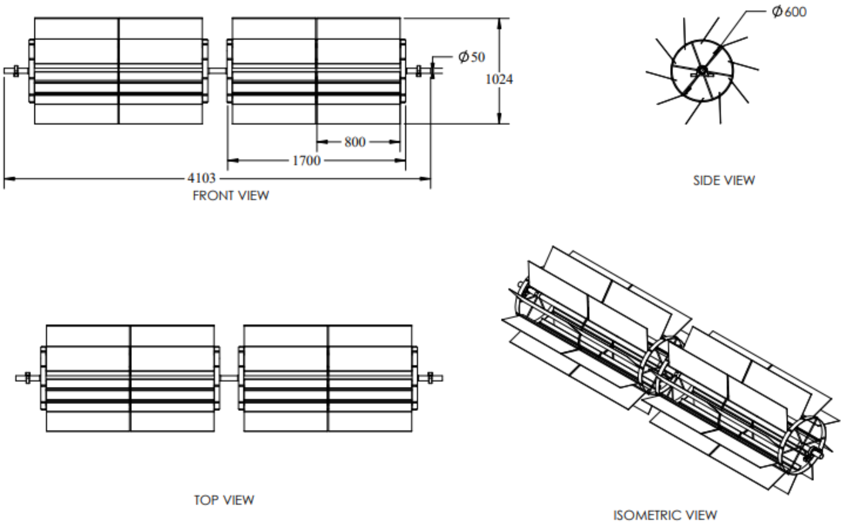

Fig. 1 2D model of the turbine

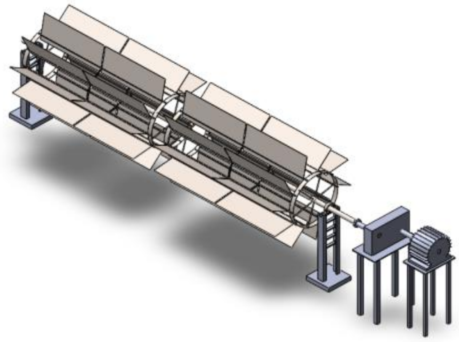

Fig. 2 3D model of the turbine

Table 4.1 Dimensions Table

Si.No.	Specifications	Units(m)
1.	Diameter of the shaft (D)	0.045
2.	Length of the blade (L_B)	0.8
3.	Width of the blade (W_B)	0.3
4.	Thickness of the blade (T_B)	0.002
5.	Diameter of the wheel (d)	0.62
6.	Hub diameter (D_H)	0.05

III. METHODOLOGY

The turbine is arranged in the water flow channel. The contact between water and blades can be adjusted mechanically. Experiment can be done by varying the depth of blade immersion, whenever water hits the blades of turbine, turbine rotates there by converting flowing water kinetic energy in to mechanical energy. The mechanical energy is converted into electrical energy by using alternator. Due to huge contact area between water and blades, high torque is obtained and step-up gear box system helps in increasing the speed of the alternator and more power is produced. In this project, 10 sets of blades are used in order to increase area of contact of the water on blades. The contact between water and blades are adjusted by hydraulic jack. The velocity of water can be increased by rectangular nozzle placed before the water wheel. Speed of the turbine, Velocity of water, power produced are measured and calculations are done to find the efficiency of the water wheel. The results of the experiment are presented in the form of tables and graphs.

IV. WORKING PRINCIPLE

Water flows in an open water channel with certain velocity hits the blades of the turbine due to this turbine rotates with certain speed, Turbine speed can be varied by varying the depth of immersion of blades in the water. kinetic energy of water converted into mechanical energy of the turbine. The mechanical stand with stopper mechanism is used for height adjustment. The weight of turbine is more, so it is easy to lift up and down turbine to certain immersion by using mechanical stoppers. Plummer block is used to provide support for a rotating turbine shaft with the help of compatible bearings and various accessories. Turbine shaft is coupled with gearbox shaft using couplings. Step-up Gearbox drive & Belt drive can be used to increase the speed of the shaft. Alternator connected to the drive shaft converts mechanical energy into electrical energy.

V. FLOW SIMULATION OF SINGLE STAGE WATER TURBINE

Computational Fluid Dynamics [CFD] is a field that deals with solutions of flowing fluids through numerical analysis techniques. SolidWorks flow simulation is used to analyze the design and to get theoretical data useful for the next step.

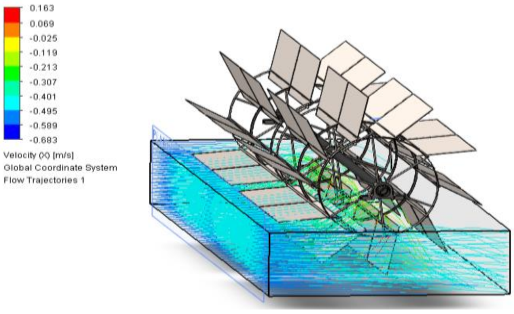

Fig. 3 Flow Simulation Results

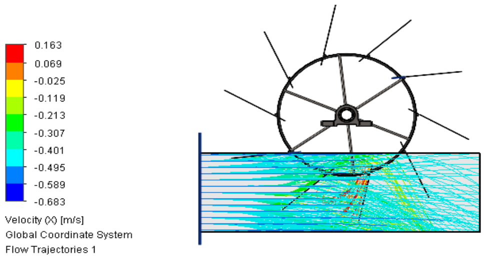

Fig. 4 Flow Simulation Results

	Depth of Immersion (m)									
	0.1	***0.2***	***0.25***	***0.27***	***0.29***	***0.32***	***0.35***	***0.39***	***0.41***	***0.45***
Power Produced for various values of Velocities (kW)	0.06	0.10	0.13	0.20	0.16	0.15	0.15	0.16	0.16	0.16
	0.08	0.14	0.17	0.27	0.21	0.24	0.21	0.22	0.23	0.22
	0.15	0.25	0.33	0.51	0.41	0.39	0.39	0.40	0.41	0.40
	0.39	0.52	0.68	0.96	0.80	0.77	0.76	0.79	0.80	0.80
	0.58	0.75	0.99	1.39	1.16	1.11	1.10	1.13	1.15	1.26
	0.70	1.02	1.34	1.89	1.57	1.52	1.50	1.54	1.57	1.75

Fig. 5 Flow Simulation Results at different velocities

The analysis is done by using different velocity values varying from 0.5m/sec to 1.5m/sec. Speed of the turbine is kept constant of 300rpm and alternator capacity is set to 1kW at 300rpm. The speed of the turbine is estimated to be 300rpm with gear drive and belt drive.

VI. RESULTS AND DISCUSSIONS

SolidWorks Software is capable of providing torque values for different velocities and by using $P = \frac{2\times\pi\times N\times T}{60,000}$ equation Shaft power is calculated, alternator efficiency of 75% is used as a standard value to find the electric energy estimation.

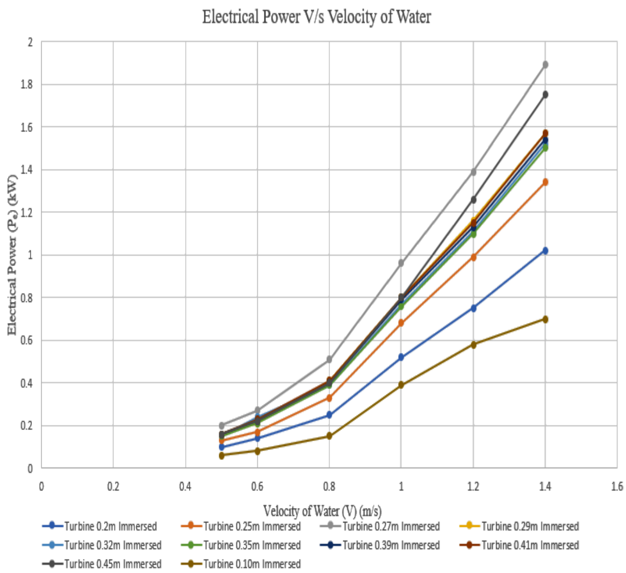

Fig. 9.11 Velocity of water (m/sec) VS Electric Power (kW)

Above graph shown is the variation of electrical power with respect to the velocity of the water. From the graph it can be observed that electrical power produced in turbine with 0.27m immersion is more compared to other depths of turbine immersion. Overall Efficiency of the design is found to be η= 64%. This value is corresponding to velocity of 1.5m/sec, 0.27m immersion and 300rpm.

VII. ADVANTAGES

1. It is Possible to harness energy from low or moderate velocity of water.
2. Hydro energy is renewable energy hence it is cheaper.
3. Single Stage water turbine does not require casing for turbine blades.

4. Installation and maintenance of single stage water turbine is easy.

VIII. DISADVANTAGES

1. Single stage water turbine creates low rpm and hence not suitable for high power requirements.
2. It requires more research work and optimization in order to obtain more power.

IX. CONCLUSIONS

The project aims in utilizing water resources effectively based on the parameters like, velocity, torque and low head of water. CFD analysis shows overall efficiency of the turbine is 64% & this answer is completely theoretical. On fabrication of the actual turbine using same data and design it is possible to get efficiency very near to this theoretical value. This design can be implemented for high power generation if water with high velocity of up 3m/sec is available to produce more power using higher capacity alternator.

X. ACKNOWLEDGMENTS

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XI. REFERENCES

[1] S. U. Patel, "Study on power generation by using cross flow water turbine in micro hydro power plant", *International Journal of Research in Engineering and Technology*, Vol.4, Issue 5, 2015, pp. 1-4.
[2] A. Sathe, "Energy Generation Using Portable Water Turbine", *JETIR*, Vol. 6, Issue 4, 2019, pp.1-8.
[3] A. H. Elbatran, "Hydro power and turbine systems reviews", *Journal Technology* (Science & Engineering, Vol.5, Issue 5,2015, pp.1-8.
[4] D. R. Verma, "Horizontal Axis Water Turbine: Generation and Optimization of Green Energy",*International Journal of Applied Engineering Research*, Vol. 13, Issue 5, 2018, pp.1-9.
[5] G. Muller, "Water Wheels as Power Source", *International journal on renewable energy*, Vol. 7, Issue 8, 2016, pp.1-8.
[6] K. P. Huparikar & G. R. Naik, "Development of Prototype Turbine Model for Ultra-Low Head Hydro Power Potential in Western Maharashtra", *IOSR Journal of mechanical and civil engineering*, Vol. 12, Issue 9, 2015, pp. 14-20.
[7] O. Paish, "Small hydro power: technology and current status", *International journal in Renewable and Sustainable Energy Reviews*, vol. 6,2002, pp. 1-20.
[8] S. J. Williamson, B. H. Stark & J. D. Booker, "Low Head Pico Hydro Turbine Selection Using a Multi-Criteria Analysis",*International Journal of World Renewable Energy Congress*, Vol.14, Issue 10, 2011, pp.1-20.