Design and Fabrication of Flywheel Turbine

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Abstract- Hydropower is a renewable source of energy, which is economical, nonpolluting and environmental friendly among all renewable sources of energy. Hence, hydropower has become one of the most suitable and efficient source of renewable energy. Flywheel turbine is a new type of low head impulse turbine that is specifically built to harness energy from water stored at very low heads i.e.1 to 3m.The conventional Pelton turbines are used for power generation from water stored at high heads. The conventional reaction turbines such as Kaplan turbine are used for power generation at low heads but they are complex in design. Hence, the fly wheel turbine is an impulse turbine designed in such a way that it is simple in design and can be used at low heads. This work is purely intended to enhance the efficiency of the turbine with the modification in the blade design and some of the auxiliary attachments which ultimately lead to the enhancement of the efficiency of impulse turbines for low heads.

Index Terms- Impulse turbines, Flywheel turbines, semi cylindrical buckets, Alternator

I. Introduction

Energy is an important factor for economic growth, social development and human welfare of developing nations. The role of renewable energy in tomorrow's world is of great significance for the global environmental stability. Sun, Wind and flowing or stored hydropower are considered the most renewable source for power generation. Out of these three renewable energy resources, the advantage of hydro energy is that it can continuously supply energy and can serve as a base power. The annual global hydropower production is very small compared to the global power consumption. The world hydropower scenario shows that the technically exploitable potential of hydro energy is about 14000TWh/year and the economically exploitable potential is about 8000TWh/year, whereas the present global hydropower generation stands at 2800TWh/year. Looking at the above estimates it is clear that there a large potential of hydropower waiting to be exploited.

Impulse turbines which have the least complex design are most commonly used for high head hydro systems, whereas the type of turbine used for low head hydro sites are of reaction type. Reaction turbines are very complex in design therefore they are very expensive. There are many ultra-low head sites nearby that have hydraulic heads ranging from 1m-3m that are only used to store water for irrigation. During rainy season these dams overflow and a lot hydraulic energy gets wasted. The proposed system is developed to harness energy from low head sites using an impulse turbine. The work is purely intended to enhance the efficiency of the turbine with the modification in the blade design and some of the auxiliary attachments which lead to the enhancement of the efficiency of the impulse turbine with low heads.

Micro energy extraction

Normally, people do not extract micro or small amount of power from the water stored at low heads because of the difficulties in installing the turbine, huge construction work and maintenance required.

In a state, maximum of 2 to 3 hydropower station will be there which extract energy on a large scale. (In terms of MW). But micro hydropower of 0.5KW to 10KW can be extracted from a large number of potential sites like vented dams. If a turbine which is inexpensive, requires less construction work and low maintenance is designed. The usage of hydropower and extraction of micro power from water increases to a greater extent.

Pelton wheel is an impulse turbine which is more suited for high heads but in general, water with high head potential sites are very less and also it requires a construction of penstocks which increases the construction costs.

Kaplan turbine which is suitable for low heads, requires construction of draft tube which is difficult in construction and also its installation and maintenance is difficult. Reaction turbines must be encased, if some obstacles like water bottles, wood, plastics or any other objects enter the turbine, blades of Kaplan turbine get damaged and also maintenance is difficult.so filtration of water at inlet is required for Kaplan turbine which increases work and cost.it is the main hurdle because of which it is not used for micro energy extraction.

If we construct an impulse turbine that is open to atmosphere, self-cleaning and does not require any draft tube, filtration of water and huge penstock, then usage of micro hydropower will increase.

In the present work an attempt is made to construct a turbine, which overcomes the above disadvantage of Pelton and Kaplan turbine.

II. LITERATURE REVIEW

Kiran P et al. [1] developed a prototype of ultra-low head turbine, designed specifically for very low head sites in western Maharashtra region. The objectives of the design of the ultra-low head hydro power turbine was to develop a propeller turbine that will require very few civil work, will be easy to install and will offer a high degree of reliability at a reasonable cost per installed KW.Power output of 200 watts was obtained with 80% efficiency. **Paritosh singh** et al. [2] carried out an analytical review of impulse and reaction turbine on the basis of type of action of the water on the blade. Here a modified gravitational Pelton wheel turbine was designed for low head and heavy discharge applications. Here the authors have come to the conclusion that reaction turbines are more efficient than impulse turbines.

Prof .N.P.Jade et al. [3] undertook theoretical analysis of simple reaction water turbine for ultra-low head. An enhanced computer model of simple reaction water turbine was developed for optimum turbine sizing for a given head and speed. The turbine was tested in a free water stream environment and the maximum power generated was 8watts at 100 rpm which is too low.

From the papers discussed, it is observed that results from studies that considered reaction turbines for low head conditions did not yield good results. The work described in paper [2] is about modifying a convention Pelton wheel for low heads. Here, no modifications to blade design were done and only effect of gravity on the turbine blades was analyzed. Hence, in this project an attempt has been made to make use of gravitational impulse turbine for power generation at low heads by utilizing the data obtained from the research papers.

III. WORKING PRINCIPLE

The Flywheel turbine is mainly designed to work under low head conditions, the stored water from a vented dam is made to flow along a water channel which converges or directs the water into the nozzle. Nozzle converts the pressure energy of water into kinetic energy. Water is made to flow through a rectangular nozzle which increases the velocity of water and provides a line load to the turbine buckets. The nozzle directs the water in a tangential direction on to the buckets to get more power input. Semi cylindrical buckets are attached to the specially designed pulley as shown in the fig 1.pulley acts like a flywheel as well as speed increaser. Water after transferring the momentum to the blades will not be allowed to go out of the turbine hence torque increases. The pulley is coupled to an alternator with a belt drive arrangement.

Even though the speed of rotation of turbine decreases because of weight of water, there will be significant increase in the torque specially in case of high discharge of water, during which large quantity of water will be hitting the blades and as the density of water is very high, one litre of water acts as 1kg of load on the turbine blades and helps to overcome the backload provided by the alternator. Water will be held inside the turbine only during the first half of the rotation of the turbine, all water will be expelled out during second half of rotation of the turbine

Normally Pelton turbine is said to be less efficient and not suitable for low head conditions. This is because there will be significant drop in the speed of rotation of the turbine when load is applied on the alternator. But in flywheel turbine the weight of water acts on the blades and extra effect of gravity acts on the blades leading to increase in torque and lesser drop in speed of rotation of the turbine, thereby make the turbine suitable for low head conditions.

In the hydropower plants, the available hydraulic energy exists as potential energy, which is measured in the form of the geodetic height difference between the upper level of water in the reservoir and the altitude at which water strikes the turbine buckets. This height difference is denoted as hydraulic head in the terminology of hydro power.

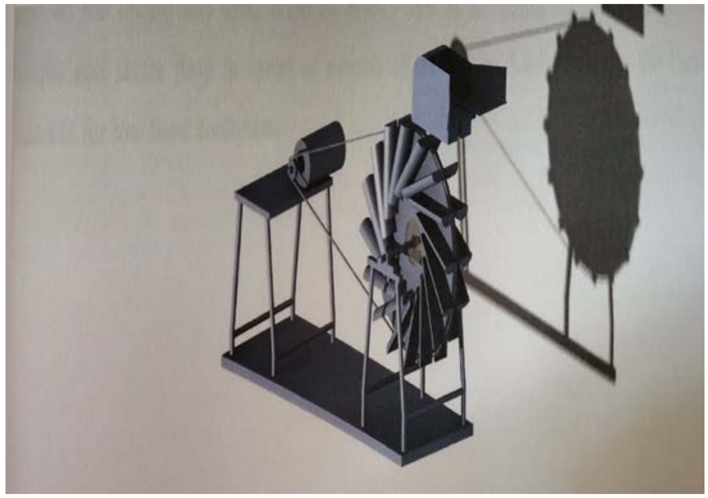

Fig. 1 CATIA model of flywheel turbine

IV. DESIGN CALCULATIONS

Number of buckets on each side (Z)

- Pitch diameter, D = 800mm
- Breadth, b = 450mm
- Width, w = 80mm
- Cross sectional area of Nozzle,

A_c= (breadth × width) (1)

- Wetted perimeter of rectangular Nozzle,

P=2(breadth + width) (2)

- Hydraulic diameter d_h,

$$d_h = \frac{4A_C}{P} = \frac{4\times(450\times80)}{2\times(450+80)} = 135.8\text{mm} \quad (3)$$

- Number of buckets on each side z,

$$Z = \frac{D}{2d_h} + 15 = \left(\frac{800}{2\times135.8}\right) + 15 = 17.9 \quad (4)$$

- Z=18

Even though the no of buckets obtained on each side was 18, to avoid unbalancing even number of buckets was attached onto each quadrant of the pulley. Therefore the number of buckets has been reduced to 16 on each side.

Power input

Input power is the amount of energy possessed by the inlet water. In low head impulse turbine potential energy as well as the kinetic energy of the fluid is very low.so the major part of the energy is obtained by the weight of the water.

Input power $P_{in} = \rho g Q H$ (5)

Here,

ρ – Density of water (1000 kg/m^3)

g- Acceleration due to gravity (9.81 m/s^2)

H- Head of water

Q-Discharge (m^3/s)

- $P_{in} = \rho QgH$
- $P_{in} = 10^3 \times 60 \times 10^{-3} \times 9.81 \times 1.23$
- P_{in}=723.9 watts

Diameter (D_1) of larger pulley

- Diameter of smaller pulley D_2=76mm
- Speed of the smaller pulley required N_2=500 RPM
- Speed of the bigger pulley (speed of turbine)N_1=42RPM

Formula used (from design data hand book)

$$N_1 D_1 = N_2 D_2 \quad (6)$$

- $D_1 = \frac{76 \times 500}{42}$
- D_1=904.76mm
- Standard diameter of 36 inches i.e.914.44mm is chosen

Length (L) of belt

$$L = 2C + \pi\left(\frac{D_1 + D_2}{2}\right) + \left(\frac{(D_1 + D_2)^2}{4C}\right) \quad (7)$$

Where

L-Belt length in mm

C-Centre length between two pulleys in mm= 1410mm

D_2=Pitch diameter of first pulley in mm = 76.2mm

D_1=Pitch diameter of second pulley in mm= 914.44mm

- $L = (2 \times 1410) + \pi\left(\frac{914.44 + 76.2}{2}\right) + \left(\frac{(914.44 + 76.2)^2}{4 \times 1410}\right)$
- L=4550.09mm≅ **4.5**m
- Standard length of 4.5m is chosen

Determining the position of the nozzle

Nozzle is an important part of the flywheel turbine system.it is used to increase the velocity of water flowing on to the turbine buckets. Conventional impulse turbines make use of nozzles that direct forceful, high speed streams of water against a rotary series of spoon shaped buckets, which are mounted around the circumferential rim of a driver wheel. Here, nozzle is situated at the bottom and the water jet impinges upon the contours of the bucket sideways from the bottom. But in flywheel turbine the rectangular nozzle is situated at the top of the turbine. Semi cylindrical buckets are mounted on to the surface of the pulley, thus the water after impinging the buckets gets stored in the buckets. Hence, the effect of gravity increases the performance of the turbine. To determine the optimum position of the nozzle water with same discharge and velocity was impinged on to the turbine buckets from various positions as shown in below fig 2.

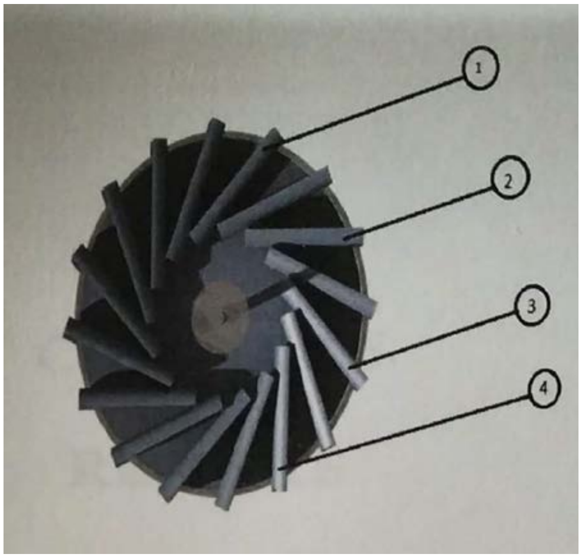

Fig. 2 Flywheel turbine

Table 1 Determination of nozzle position

Position of nozzle	Turbine speed
1	42.7
2	44.3
3	38.6
4	21

V. RESULTS AND DISCUSSIONS

Test results at site conditions

The testing of the turbine was carried out at dam site having a head of 1.23m.The results of the test are given in table below. Power output of 500 watts is obtained with an overall efficiency of 69.07%.

Table 2 Test Results

Sl No.	Alternator Speed (RPM)	Turbine speed(RPM)	Hydraulic input power (W)	Electric output power (electric load) (W)	Efficiency %
1	700	58	723.9	0(no load)	0
2	400	33	723.9	200	27.62
3	320	27	723.9	300	41.44
4	260	22	723.9	400	55.25
5	200	17	723.9	500	69.07

Also, a plot of electrical load against overall efficiency shows that the efficiency of the turbine increases with the increase in electrical load. Maximum efficiency of 69.07% is obtained for a load of 500 watts, which was the maximum load that alternator could handle.

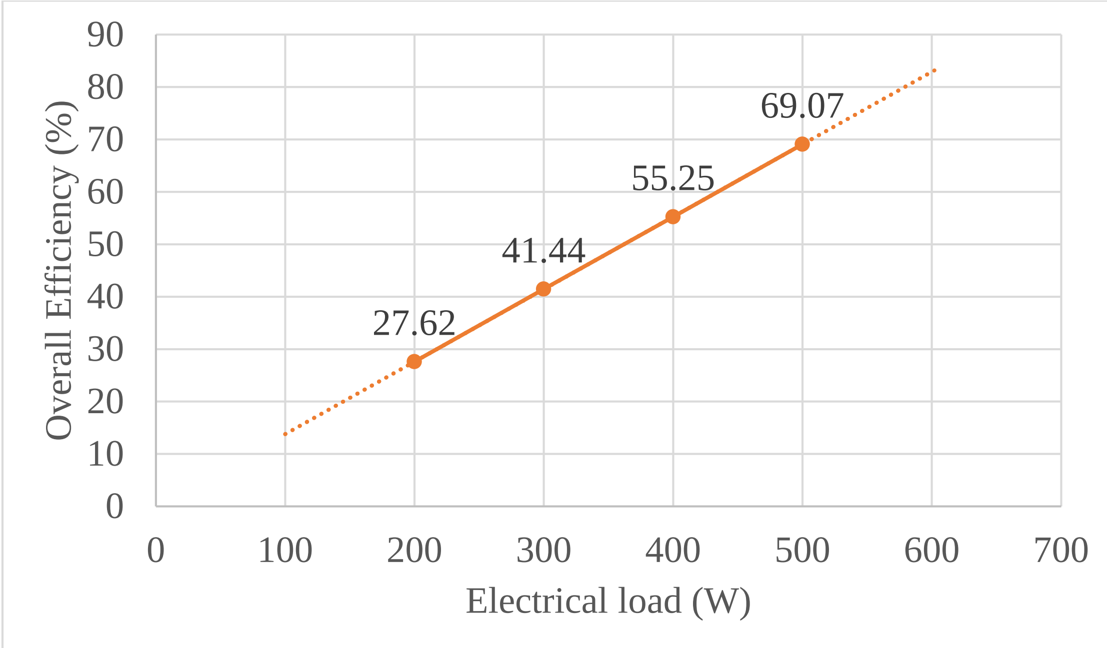

Fig .3 Electrical load v/s Overall efficiency

Comparison between Flywheel turbine and Kaplan turbine

Kaplan turbines are the type of turbines used for low head conditions. Table 2 represents the table that compares results of performance test conducted for Kaplan turbines at lab conditions and the results obtained from tests conducted for flywheel turbines at site conditions.

The table below shows the comparison of flywheel turbine with Kaplan turbine.

Table 3 Comparison of Kaplan turbine with flywheel turbine

Kaplan turbine			Flywheel turbine		
Discharge Q (LPS)	Head H (m)	Power output (W)	Discharge Q (LPS)	Head H (m)	Power output (W)
46	7.6	200	60	1.23	500
37	5.63	150	36	2	500
26	2.63	0	24	3	500

It can be observed from the table that at head of 5.63m and discharge of 37 LPS Kaplan turbine produces only 150 watts. Whereas flywheel turbine produces 500 watts at a head of 2m and discharge of 36 LPS.Flywheel turbine at a head of 1.23m and discharge of 60LPS still produces a power output of 500 watts. Whereas the Kaplan turbine fails to produce any power at similar head and discharge. This shows that flywheel turbine is more effective at low head conditions than Kaplan turbine.

VI. ADVANTAGES, DISADVANTAGES AND APPLICATIONS

Advantages

Low exit velocity of water. Hence, less loss of hydraulic energy.

No draft tube. Hence, simple in design and less construction cost.

Suitable for micro energy extraction. Utilizes renewable source of energy and costs less compared to that of wind and solar energy.

Only high discharge impulse turbine.

Uses line load nozzle. More power input is obtained.

Disadvantages

The size of the turbine gets larger per unit increase in power output when compared to that of Pelton wheel.

Applications

Flywheel turbine can be used to generate electricity from hydro dam sites having low heads.
Flywheel turbines can be used to pump water**.**

VII. CONCLUSIONS

Flywheel turbine can be an excellent prospect for energy generation from lowheads.The obtained conclusions is listed below

1. The effect of gravity by impinging water from the top on to the turbine buckets produced higher turbine speed than convention way of water impingement used in Pelton wheel turbines.

2. For a head of 1.23m and discharge of 60LPS the efficiency of the turbine is 69% and power output obtained is 500 watts.

3. The test results for the flywheel turbine at site conditions compared to Kaplan turbines at lab conditions with similar head and discharge show that flywheel turbine is better for power generation at low head sites than convention Kaplan turbines.

Scope for further work

The existing flywheel turbine has an overall efficiency of 69%.the overall efficiency and performance of the turbine can be further enhanced by making some design changes. Some of them are listed below.

1. The turbine can be provided with casing to increase the amount of water getting stored in each bucket.

2. Changes can be made to the design of nozzle to increase the velocity of water impinging the buckets.

3. Semi cylindrical buckets can be replaced by semi spherical buckets.

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