IJREAT International Journal of Research in Engineering & Advanced Technology, Volume 2, Issue 1, Feb-Mar, 2014
ISSN: 2320 - 8791
www.ijreat.org

Design, Fabrication & Testing Of A Waterwheel For Power Generation In An Open Channel Flow

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Abstract: Hydropower is the cheapest way to generate electricity today. No other energy source, renewable and non-renewable, can match it. In the developing nation like India, with the increase in population and rise in the usage of electricity is increasing at an alarming rate. **The following paper gives an idea about efficient use of water wheels in an open channel flow which gives cheap, low scale power generation solution for simple electrification purpose.** This is achieved by a horizontal axis **waterwheel** attached to a Dynamometer, converts mechanical energy into electrical energy, with the help of a belt and pulley arrangement. The full bridge rectifier allows for electricity to be transmitted in its most efficient form while still being able to power ordinary direct current into pure direct current. Regulator to regulate a current and a battery to store it. The following paper explains the working principle, functioning, design with calculations, challenges, and applications along with future scope of the horizontal axis type waterwheel.

Keywords: Hydropower, waterwheel, flywheel, dynamo, open channel.

I NOMENCLATURE

A_{bt}	=	Total area of blade (m^2)
A_{bd}	=	Area of blade dipped in water (m^2)
N	=	Number of blades (m)
L	=	Length of blade (m)
B	=	Breadth of blade (m)
m	=	Mass of flywheel (kg)
K	=	Radius of gyration (m)
I	=	Moment of inertia of flywheel (kg-m^2)
A_t	=	Total area of channel (m^2)
V_r	=	Velocity of flow (m/s)
Q	=	Discharge (m^3/s)
λ	=	Tip speed ratio
Cp	=	Power coefficient
ρ	=	Density of water (kg/m^3)
Dr	=	Diameter of rotor (m)
Ar	=	Area of rotor (m^2)
i	=	Current
v	=	Voltage
Po	=	Power output (watt)
Pi	=	Power input (watt)
η	=	Efficiency (%)

II INTRODUCTION

Energy is the most important and one of the major driving factors for a country's economy. Demand for electricity is not steady; it goes up and up. People use more electricity during the day when they are awake and using electricity appliances and less at night when they are asleep. People also use more electricity when the weather is very cold or very hot. Therefore access to electricity is particularly crucial to human development as electricity is essential for certain basic activities like lighting, refrigeration, running household appliances etc. As the time is accumulating the technology getting involved more and more in human's life. Result in more consumption of electric energy.

Hydro resource is one of the most potential energy resources among the other interesting resources such as solar cell, geothermal, fossil and hydrogen energy systems. Hydro resources can be considered as a renewable and sustainable rural energy system because it is obtainable in the free environment mainly on a water landscape [1]. Hydropower on a small-scale is one of the most cost-effective energy technologies to be considered for rural energy systems in less developed countries.

Hydro-turbines or water wheels convert water pressure into mechanical shaft power, which can be used to elevate water or to drive an electricity generator. The power obtainable is proportional to the product of pressure head and volume of flow rate. The flow of water from the channel/injector enters to blade with high velocity, then continuously rotates the wheel and elevates the water simultaneously.

III ENERGY AGENCY FACTS

Recently India's reputed news paper *The Indian EXPRESS* (Monday/ December 30/ 2013) has revealed that "the Government has not been able to achieve its target in electrifying 82 districts under Rajeev Gandhi Grameen Vidyutikaran Yojana (RGGVY)."[2] Some of these districts are MALKANGIRI and RAYAGADA in Orissa and BASTAR, DANTEWADA and SURGUJA in Chhattisgarh.

As per the present scenario, the International energy agency (IEA) in its survey of 2010 found the following facts:

- 1.6 billion People in the entire world live without electricity.
- This is around one fifth of total world population.
- 404 million people in India live without electricity.

Thus, the present scenario is not very good regarding power requirements of our country. In rural areas of our country, the scenario is still worse about 1, 12, 400 villages haven't seen what electricity is! As such, India is a land of villages and 70% of countries population lives in villages. It is high time for us to think about the power deficiencies in the country, specially the electrification of villages and remote areas where electricity is still not available.

As per Ministry of Power, out of total electricity production, 65.8% comes from thermal power plants, 26.3% from hydro electricity & only 3.1% from nuclear power. Non-conventional, renewable energy sources like solar, wind energy constitute nearly 4.9%.

At the current rate of consumption & production, coal reserves in India would last for about 130 years and oil would last only for about 20 to 25 years. In spite of these facts 65% of electricity is produced from these commercial sources which are on the verge of extinction. On the other hand hydropower even after being a renewable energy source is used for producing electrical energy accounting just for 20% of the total energy generation.

IV AIM AND OBJECTIVE

The power from streams has been in interest for electricity production for many years. This project will focus on small scale stream current turbines with the output of 0.5-5 kW. This turbine is to be used for domestic and various other general electricity applications such as lighting and battery charging etc. in rural and urban areas. Water current turbine generates power from the stream current kinetic energy without using a dam.

The main objective of this project is

- To prove that the design of the simple horizontal axis waterwheel can generate power in form of electricity using sewage water.
- To analyze the power output that can be generated from the designed Turbine.

V INDIA WASTE GENERATION SCENARIO

Every year, about 55 million tones and more of municipal solid waste (MSW) and 38 billion liters of sewage and more are generated in the urban and rural areas of India. In addition, large quantities of solid and liquid wastes are generated by industries. It is estimated that the amount of waste generated in India will increase at a per capita rate of approximately 1-1.33% annually.

VI INDIA WASTE TO ENERGY POTENTIAL

According to the Ministry of New and Renewable Energy (MNRE), there exists a potential of about 1700 MW from urban waste (1500 from MSW and 225 MW from sewage) and about 1300 MW from industrial waste. The ministry is also actively promoting the generation of energy from waste, by providing subsidies and incentives for the projects. Indian Renewable Energy Development Agency (IREDA) estimates indicate that India has so far realized only about 2% of its waste-to-energy potential. A market analysis from Frost and Sullivan predicts that the Indian municipal solid waste to energy market could be growing at a compound annual growth rate of 9.7% by 2013.

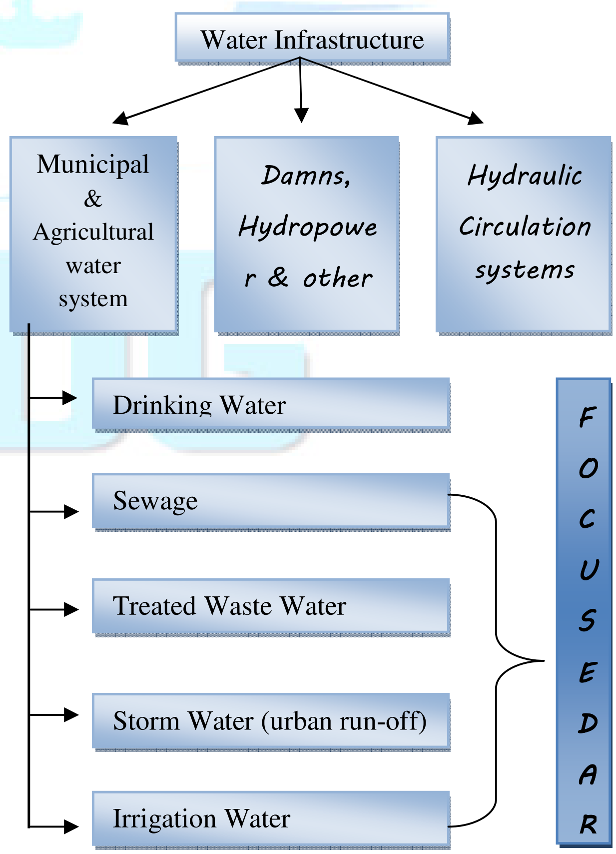

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Fig.1 Water Infrastructure and Hydraulic Structure

VII WATERWHEEL

A water wheel is a machine for converting the energy of free-flowing or falling water into useful forms of power. It consists of a large wooden or metal wheel, with a number of blades or buckets forming the driving surface. The two main functions of water wheels were historically water-lifting for irrigation purposes and as a power source. In terms of power source, water wheels can be turned either by human or animal force or by the water current itself. Water wheels come in two basic designs, either equipped with a vertical or a horizontal axle. Waterwheels are most proposed or implemented devices for the extraction of energy from a flowing stream are Kaplan or Cross flow turbines. But they require high unit capital cost/KW that requires large scale applications to make them economical. Hence, it is useful to explore alternative concepts which may be more cost effective and more practical in remote and hostile locations.

Waterwheel is the first man made method to replace humans and animals force for generating mechanical energy. It is a rotating mechanical element which converts water power (K.E. & P.E.) into useful energy. Waterwheels are classified into four different types as given below:

1. Overshot Waterwheel
2. Undershot Waterwheel
3. Breast shot Waterwheel
4. Stream Waterwheel

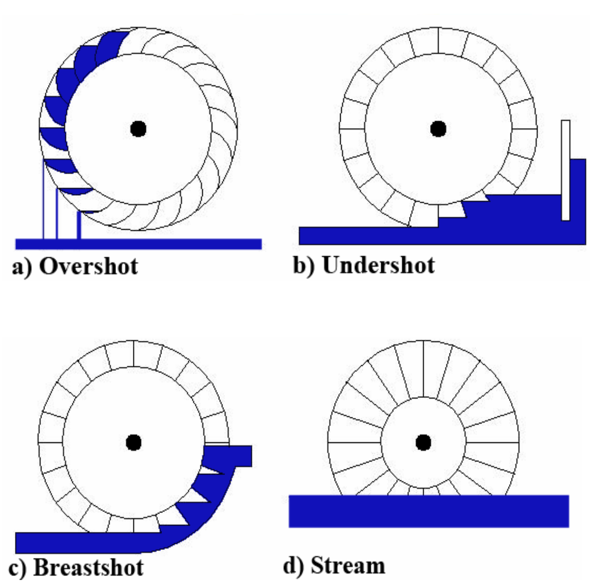

Fig.7.1 Types of waterwheels

Of the above types a stream waterwheel is chosen for this project as it is the most suited to low head flow as typified by nearshore tidal induced currents or in lowland rivers, as it is an impulse device, working through extraction of kinetic energy.

VIII REVIEW OF LITERATURE

- Development of a floating tidal energy system suitable for use in shallow water by S.R. Turnock & G. Muller gives the idea about the design of waterwheels which is useful in the electricity generation in shallow water. It may be possible that properly designing the waterwheel, the electricity generation is possible even in shallow as well as stream line water.
- International conference on small hydropower held in srilanka october 2007. in this conference sudhirmali and y.s. rana very precisely concluded the difference between the large and small hydro power sectors.

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IX BLOCK DIAGRAM OF THE SYSTEM

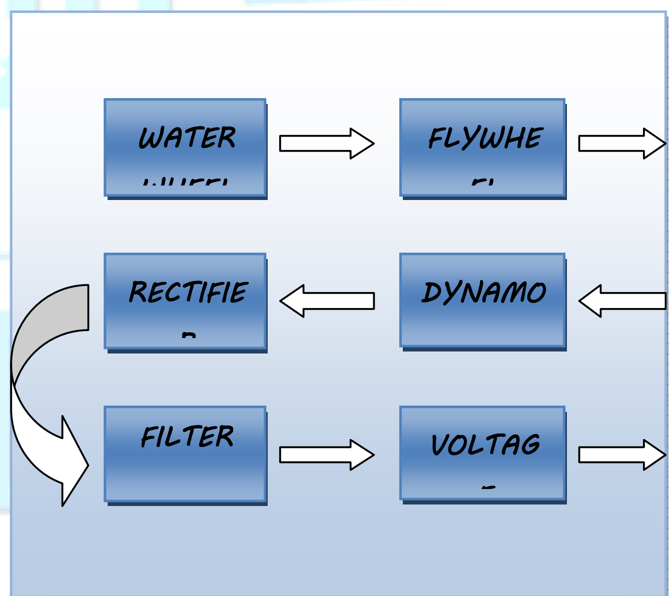
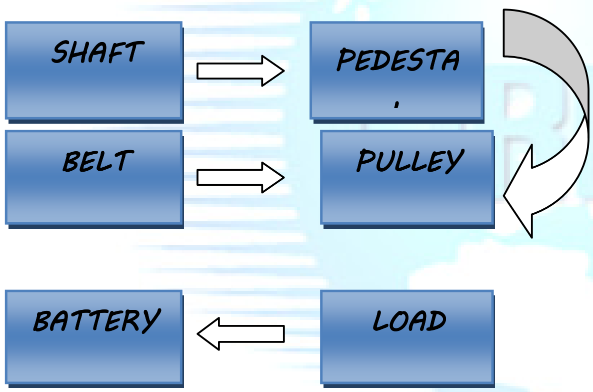


Fig.9.1 Block diagram of a system

- On that basis it is clear that sewage water though not so clean source of water but is a renewable source of energy available round the clock. It is free from many issues and controversies that continue to hound large hydro like submergence of forests, siltation of reservoirs, rehabilitation and relocation

- Another benefit of small hydro are user-friendliness, low initial and runniA book on water power gives the basic structure of water sources, its different types of flows.
- With the help of these references we came to know that unlike the seasonal fluctuation of solar and wind energy, small hydro power can provide constant year round electricity to small villages and remote locations as there is plenty of sewage water.
- The electricity generation using sewage water is a pollution free concept, it has very low impact on the environment and it is efficient in actual as there is no wastage of any kind of fuel and energy.



X SPECIFICATION

Sr. No.	Entity	Dimension(cm)
1.	Waterwheel Diameter	110
2.	Extension length	27.5
3.	Shaft diameter	20
5.	Flywheel diameter	15
6.	Pulley diameter	8

A. BLADE

No. of blades (n) = 8

Why 8 blades?

- Only 1 blade to be dipped at a time.
- To prevent backflow due to immersion of more than 1 blade at a time.

Next blade comes in contact with water as soon as the previous one is passed thereby maintaining a constant inertia at the flywheel.

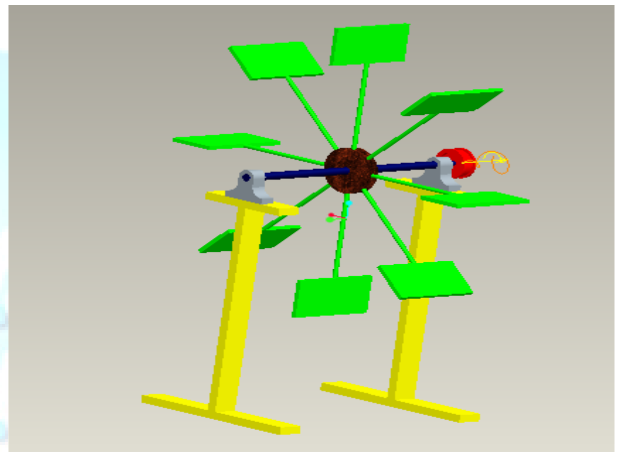


Fig.10.1 Waterwheel Design

XI CALCULATIONS

Total area of blade (A_{bt}):

A_{bt} = L x B

= (20 x 12.5) cm²

= 250 cm²

= 0.0250 m²

For 50% immersion of blade length:

Area of blade dipped in water (A_{bd}):

A_{bd} = (0.5 x L) x B

= 0.5 x 20 x 12.5

= 125 cm²

= 0.0125 m²

Rpm obtained at 50% blade length immersion = 7

A. FLYWHEEL:

a. Mass of Flywheel (m):

m = $\pi \times (R-r)^2 \times b \times \rho$

= $\pi \times (0.075-0.01)^2 \times 0.025 \times 7800$

= 2.58kg

b. Radius of Gyration (K):

K = $\frac{(R-r)}{\sqrt{2}}$

= $\frac{(0.075-0.01)}{\sqrt{2}}$

= 0.045 m

c. Moment of Inertia of Flywheel (I):

I = $m \times K^2$

= 2.58 x 0.045

= 0.1161 kg-m²

Total area (At) = 0.505 m²

Velocity (v) = 0.5 (by float method)

Discharge (Q) = At x V

= 0.505 x 0.5

= 0.2525 m³/s

Tip speed ratio (λ) = 0.35

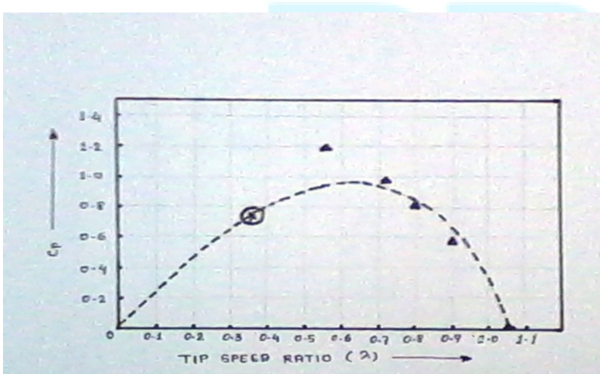


Fig.11.1 Power coefficient Vs Tip speed ratio

B. *POWER INPUT* (Pi)

Pi = $0.5 \times Cp \times \rho \times Ar \times v^3$

= $0.5 \times 0.8 \times 1000 \times \frac{\pi}{4} \times (Dr)^2 \times (0.5)^3$

= $0.5 \times 0.8 \times 1000 \times \frac{\pi}{4} \times (110-15)^2 \times 10^{-2} \times 10^{-2} \times (0.5)^3$ W

= 35.441W

11.4] POWER OUTPUT (Po)

Po = i x v

= 1 x 12

= 12 W

11.5] EFFICIENCY (η):

η = (Power output/ Power input) x 100

= $\frac{Po}{Pi} \times 100$

= $\frac{12}{35.441} \times 100$

η = 34 %

XII CONCLUSION

The Waterwheel, a renewable and sustainable energy system with effective technologies, low cost of operation and maintenance is very suitable in rural area with a water landscape environment. The traditional water wheel and water mill, which were constructed with a simple design with very basic technology, have a big economic impact on the rural economy. The traditional water wheels and water mills were constructed from hardwood, bamboo and recycled components from steel functions as a new green technology promising no negative effects on the environment.

ACKNOWGEMETN:

Guided by

Pravin Gupta

Department of ME

Assistant Prof. At J.D.College of Engineering,

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