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ELECTRICITY GENERATION BY USING COOLANT TIDE

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ABSTRACT

The low head turbines are design according to local situation. In Cummins PHP plant low head produced by coolant tide is utilize to produce electrical power by using turbine and generator setup. The general concept of this turbine design project is to convert the kinetic and potential energy of the water based coolant moving with some speed (momentum) into a usable form of energy. To harness the potential, new turbines have been developed and commercially available. For the cost effective and efficient project we need to study the optimal selection of hydro turbine .The objective of this project report is to review the selection, design and performance testing of hydro-electric turbine for very low head high discharge application. The following project report gives an idea about efficient use of water wheel in an open channel flow which gives cheap, low scale power generation solution for simple electrification purpose.

Keywords: Hydro turbines, Low head turbines, Water Wheel turbine

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I. INTRODUCTION

The aim of this project is to investigate the use a head of impure coolant flow to generate electricity. This study will aim to design and develop a low head high discharge turbine to generate electricity.

In the present work, it is proposed to study and design open type low head high discharge turbine by using head produced due to coolant tide in coolant filtrations plant .

To generate electrical power by using rotation of open type low head turbine .We also use this turbine for head produced due to sewage water in city area, waste water in sugar industry and any other industry.

The following are the objective of the projects :

1) To design low head high discharge turbine.

2) To design and manufacturing of the various parts of turbine and power transmission system.

3) Performance testing of open type low head high discharge turbine.

Scope of Work

For very low head high discharge application we need to select suitable turbine. Open type low head turbine is most suitable for this application. The open type turbine assembly consist of a penstock pipe,runner (water wheel),shaft and power transmitting element that collectively convert momentum and pressure of coolant into rotational mechanical work. The runner is a mechanism that converts the hydraulic energy into mechanical power by redirecting fluid flow. The runner is typically equipped with buckets that interact with the moving coolant and cause the runner to rotate the mechanical work is transferred by the shaft to alternator.

Methodology

The software program is the heart of the system. The system also includes the designing of circuit, system interface and wireless data communication. The block diagram for transmitter and receiver are shown in figure.

Introduction to Hydraulic Turbine

Hydroelectric turbine is a mechanical devise which convert potential energy in stored water or kinetic energy in flowing water is convert in to mechanical rotational energy .Further this mechanical energy is converted into electrical energy by coupled with generator.

A hydraulic machine is a device in which mechanical energy is transferred from the liquid flowing through the machine to its operating member (runner, piston and others) or from the operating member of the machine to the liquid flowing through it. Hydraulic machines in which, the operating member receives energy from the liquid flowing through it and the inlet energy of the liquid is greater than the outlet energy of the liquid are referred as hydraulic turbines. Hydraulic machines in which energy is transmitted from the working member to the flowing liquid and the energy of the liquid at the outlet of the hydraulic machine is less than the outlet energy are referred to as pumps. It is well known from Newton’s Law that to change momentum of fluid, a force is required. Similarly, when momentum of fluid is changed, a force is generated.

This principle is made use in hydraulic turbine. In a turbine, blades or buckets are provided on a wheel and directed against water to alter the momentum of water. As the momentum is changed with the water passing through the wheel, the resulting force turns the shaft of the wheel performing work and generating power. A hydraulic turbine uses potential energy and kinetic energy of water and converts it into usable mechanical energy. The mechanical energy made available at the turbine shaft is used to run an electric power generator which is directly coupled to the turbine shaft The electric power which is obtained from the hydraulic energy is known as Hydroelectric energy. Hydraulic turbines belong to the category of roto- dynamic machinery. The hydraulic turbines are classified according to type of energy available at the inlet of turbine, direction of flow through vanes, head at the inlet of the turbines and specific speed of the turbines.

Classification of Turbine

Hydro turbines are classified into three categories which are being discussed below:

a) Impulse Turbines

Pressurized water from the penstock is converted to high-speed water jets that transfer the kinetic energy of the jet by impacting the turbine blades or cups causing rotation. The pressure drop in the water flow occurs at the nozzle and the runner operates at atmospheric pressure.

Examples of impulse turbines include the Pelton wheel turbines.

Impulse turbines generally operate best with medium or high head (above 160 m).

b) Reaction Turbines

Reaction turbines operate under pressure in an internal flow regime. Water passes the stator, which takes the form of spiral casings or guide vanes, to introduce swirl into the flow. The flow is then redirected by the runner blades. The angular momentum of the water forces rotation in the runner. In contrast to impulse turbines, the water pressure drops at the stator and the runner .

Reaction turbines often have complex blade geometries and housings, which make them more difficult to manufacture at smaller scales in a developing country setting. However, as seen in Figure 2.1, reaction turbines can perform well even in the low head range (less than 10 m), making them more desirable since low head water sources are more accessible and closer to end-use locations .

Examples of reaction turbines include propeller, Kaplan, , screw and hydro kinetic turbines (used for low head range less than 5m).

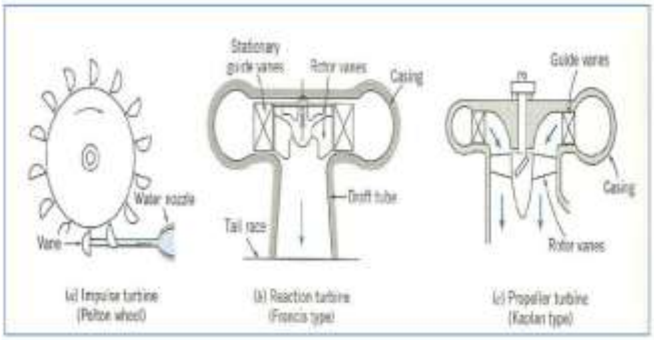

Fig.2.1 Schematic diagrams of typical hydraulic turbines [7]

c) Water Wheel turbine

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 wheel scan 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

In order to be able to utilize the head differences from 0.5 to around 12m, three basic types of water wheels were developed. Most wheels employed only the potential energy of the water.

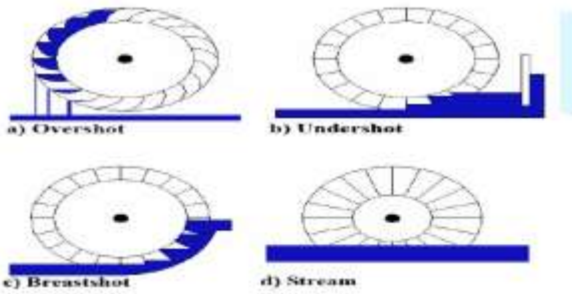

Fig. 2.2 Various type of water wheel turbine [14]

All ‚modern‘wheels have in common that they employ the potential energy of the water, and that they are built in steel.

Selection Criteria of Turbine

Hydro power designer has to make a choice on the type of turbine that can be adopted for a particular project. After the range of head to be handled by a turbine has been evaluated by stream flow analysis and the installed capacity determined from the analysis of the power generating capacity of the proposed plant, the task of the designer is to choose an optimum turbine type and series, the number of power generating units, the runner diameter, rotational speed, and runner axis elevation.

Knowing the total installation at the power station, the number of units can be decided depends on the load requirement of that particular area. The capacity of the plant should be fixed as high as possible with adequate care on efficient running and low initial costs, and available transport and shipping facilities and should not be so high so that turbine would not run at low efficiency at the time of lean season.

Basically there are two methods which help in selection of turbine are following:

1 Scientific method

2 Thumb rule

Selection of turbine for design application

Available head of coolant tide very about 1.5 m. Here we have two option either reaction turbine (Bulb turbine) or water wheel. All ‚modern ‘wheels have in common that they employ the potential energy of the water, and that they are built in steel .Because our coolant contains burs and spirals of steel this is not preferred for closed type reaction turbine. Reaction turbine such as Bulb turbine may get block or also it have a problem of cavitations. Hence we select Water Wheel for our design application. Water wheel turbine is open type working at atmospheric pressure. Therefore there is no cavitations problem and no blockage of turbine takes place.

DESIGN WORK AND SETUP WORKING

Design Work

In Cummins PHP plant head available of coolant tide is about 1.5 m.For very low head application we select open type low head water wheel turbine because it working under low head. Hence we select open type low head water wheel turbine for design consideration. Therefore we design overshot type water wheel turbine to generate electrical power from coolant tide.

Open type low head water wheel turbine

In Coolant Filtration plant coolant enters in the tank contains burs, spirals, and scrap after machining. Reaction turbine low head high turbine but cavitations problem are more prone to this turbine. This is closed type turbine hence blockage problem are generating in this turbine due to coolant contains burs and spirals.

Therefore we select open type low head water wheel turbine. Head available due to coolant tide is about 5 foot .This turbine does not prone to cavitations and blockage bur can easily pass through penstock pipe. Despite that researchers and equipment manufacturers have paid less attention to the emerging field of open type low-head power turbines, open type low head turbines can provide innovative, environmental friendly and cost-effective solutions for energy production. Power generation capacity of Open type low head turbine is similar to the Micro hydro turbine. Such low head turbine schemes have good prospects for potential use in remote location.

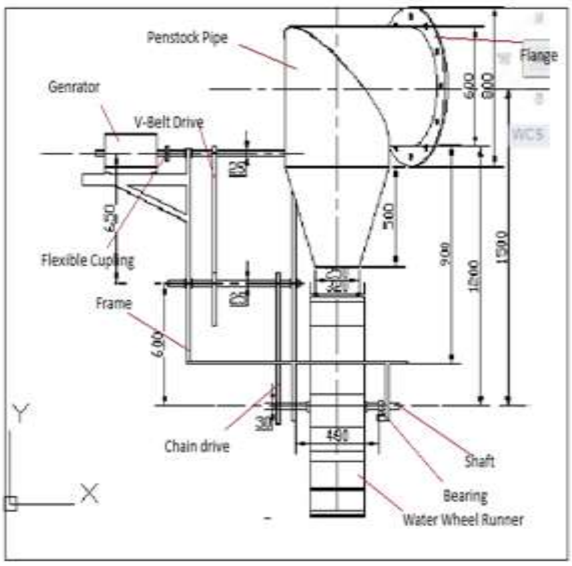

Fig.3.1 General layout of a hydro-electric open type low head water wheel turbine.

Design of Open Type Low Head Turbine

Input Parameters

Discharge = 11,000 lpm (0.183 m3/s)

Head = 1.5 meters (5 foot)

Output parameters

Power output = 2 KW

Speed of Runner Shaft = 40 to 50 rpm

Runner Diameter = 1200 mm

Inner Diameter = 500 mm

Runner Width = 425mm

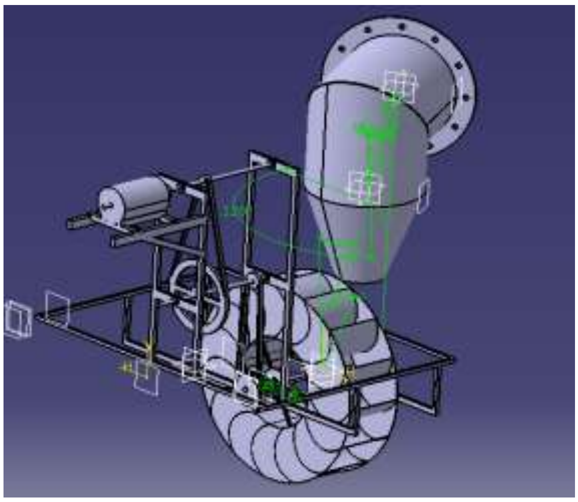

Fig.3.2 Open type Water Wheel Turbine Assembly

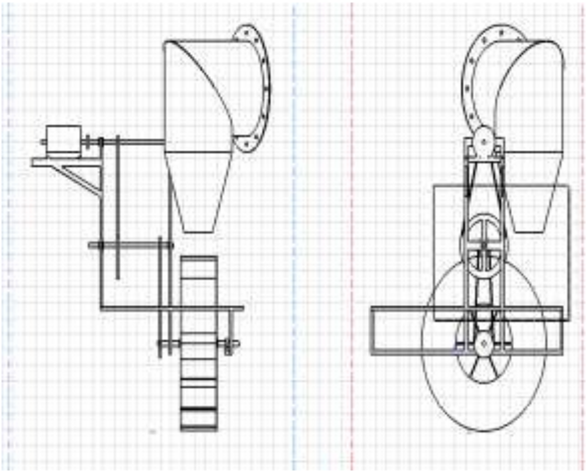

Fig.3.3 Left hand side view and Front view of open type low head Water wheel turbine.

ANLYTICAL STUDY

Design Of Turbine

1) Hydraulic Power = ρgQH

$= 1000 * 9.81 * 0.1833 * 1.5$

$= 2697.2595$ W

$= 2.697$ kW

2) Velocity of Jet (v_1)

$v_1 = 0.98 * \sqrt{2gH}$

$= 0.98 * \sqrt{2 * 9.81 * 1}$

$v_1 = 4.341$ m/s

3) Diameter of Jet (d)

$d = [\frac{4 * Q}{\pi * kv * \sqrt{2gH}}]^{1/2}$

$= [\frac{4 * 0.1833}{\pi * 0.98 * \sqrt{2*9.81*1}}]^{1/2}$

$= 0.2318$ m= 231.86 mm

4) Mass flow rate

$m_s = \rho * A * v_1$

$=1000 * 0.04220 * 4.341$

$= 183.19$ kg/sec

5) Normal forced exerted on vanes

Velocity of Vane = u = 0.48 *4.341

= 2.0834 m/s

Normal Force Fn = $m_s * (v_1 - u) * (1+ \cos\theta)$

$= 183.19* (4.341-2.0834) * (1+ \cos 0)$

=827.1395 N

5) Power Output = $F_n * u$

= 827.1359 * 2.0834

= 1723.2624 W

= 1.723 kW

6) Hydraulic Efficiency (η)

$\eta = \frac{Power\ Output}{Hydraulic\ Power} * 100$

$= \frac{1.723}{2.697} * 100$

= 63.88 %

Design of Shaft :

1) Selection of material for shaft- (C40) From design data book [15]

Sut = 640 N/mm^2

Syt = 380 N/mm^2

According to ASME code [16]

Considering Key way effect shear stress is reduced by 25 %

Shear stress = τ = 0.75 * 0.30 * Syt

= 0.75 * 0.30 * 380

τ max = 85.5 N/mm^2 (Select whichever is smaller)

$\tau = 0.75 * 0.18 * S_{ut}$

$= 0.75 * 0.18 * 640$

= 86.4N/mm^2

2) Vertical Force on Pulley :

$P_1/P_2 = e^{\mu\theta} = 2.5$

$P_1 = 2.5\ P_2$

Power Output = 2 kW

N = 60 rpm

P = 2πNT/60

$M_t = (60 * 2 * 10^{3}) / (2\pi * 60)$

M_t= 318.3098 Nm

$M_t = (P_1-P_2) * (500 / 2)$

P_2 = 848.83 N , P_1 = 2122.067 N

P_1+P_2 = 2970.89 N

3) Bending Moment Diagram :

Taking moment at point C

$(R_{AV} * 500) -(785 * 250) - (2971 * 100) = 0$

R_{AV} = 986.7 N

$\sum F_y = 0$

$R_{AV} + R_{CV} + 2971 - 785 = 0$

R_{CV} = 3172.7 N

Vertical Bending Moment Diagram

M_{BV} = 246675 N-mm

M_{CV} = 297100 N-mm

M_b max = MCV = 297100 N-mm

$M_b max = \sqrt{(Mcv)^2 + (Mch)^2}$

M_b max = 297100 N-mm

Kb = 2

Kt = 1.5

Where,

Kb= Combined Shock & fatigue bending factor for suddenly applied load heavily shock for bending.

Kt= Combined Shock & fatigue torsion factor for suddenly applied load heavily shock for torsion.

$t\ max = \frac{16}{\pi d^3}\sqrt{(M_b\ K_b)^2 + (M_t\ K_t\ )^2}$

d^3 = 35394.58 mm

d = 32.83 mm ≈ 35 mm

So shaft of 35mm diameter is selected

3) Design of key

For rectangular key

b = (d/4) = (35/4)

b = 8.75 ≈ 9 mm

h = (2/3) * b = (35/6)

h = 5.83 ≈ 6 mm

l = 1.5 d = 1.5 * 35

l = 52.5 mm

Selection of Bearing from manufacturer catalogue

L_{10} h = 30000 hr

n = 100 rpm

P = F_r = 3172.7 N

$L_{10} = \frac{60*100*30000}{10^6}$ = 180 million rev
$C = P *(L_{10})^{1/3} = 3172.7 * (180)^{1/3}$
C = 17913.75 N = 18 kN
From manufacturer catalogue at C = 18 kN (15)
Therefore bearing number 6207 is selected for the above application.

TOTAL EXPENDITURE : 40,730

Payback Period

Power output = 2 KW
Electricity generated per day =2*7 (KWhrs) =14 unit/day
Electricity generated per month = 14*25= 350 unit/month
Cost of Electricity generated per month =350*10.50= Rs 3,675/month
Cost of Electricity generated per year = Rs 3,675*12 =Rs 44,100/year
Payback period = Fist Investment cost / Annual Benefit gained
40730 /44100 = 0.9235 year = 11 months

Conclusion :

Hence we conclude that low head open type Water wheel turbine is a best suitable and efficient option for head produced due to coolant tide .It also helpful for head imparted by waste water in city area to produce electricity for small scale application. This report reviews the selection of hydro turbines for generation of power from coolant tide. This report can be a guideline for the developers in selection and design of hydroelectric turbine for available low head of coolant tide.

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