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"Analysis of Solar Turbine for Bhatsa Dam"

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Abstract - *This report gives the information about the How much power the pump will required to suck the water certain head or height of dam to start the turbine with giving the power to the pump from solar panels and how many solar panels are required for this and their cost and it will be economical or not. In Hydropower plant capture the energy of falling water to generate electricity. Turbine converts the kinetic energy of falling water into mechanical energy then generator converts the mechanical from turbine to electrical energy and this has be transmitted over some distance to it use. We have chosen the study area is Bhatsa dam for our study. The methodology will be used in this report is wearer analysing that turbine will be start on pump and giving the purpose of this report is summaries the available information and design the pelton turbine for the dam and predict the result. What difference will come out from this, where it is economical to provide solar water pump to start turbine its efficiency and its cost.*

1. INTRODUCTION

A turbine is a turbo machine with at least one moving part called a rotor assembly. This is a shaft or drum with blades attached. It is a rotary mechanical device that extracts energy from fluid flow & converts it into useful work moving fluid acts on the blades, so that they move & impart rotational energy to rotate. The pelton wheel is an impulse type water turbine which extracts energy from the impulse of moving water as opposed to water dead weight like the traditional overshot water wheel.

Turbines are defined as the hydraulic machines which convert hydraulic energy into mechanical energy. This mechanical energy is used in running an electric generator which is directly coupled to the shaft of the turbine. Thus the mechanical is converted into electrical energy. The electric power which is obtained from the hydraulic energy is known as Hydro-electric power. If at the inlet of the turbine, the energy available is only kinetic energy, the turbine is known as impulse turbine. As the water flows over the vanes, the pressure is atmospheric from inlet and outlet of the turbine. It is the inlet of the turbine, the water possesses kinetic energy as Well as pressure energy, the turbine is known as reaction turbine.

1.1 Classification of hydraulic turbines

The hydraulic turbine is classified according to the type of energy available at the inlet of the turbine, direction of flow through the vanes, head at the inlet of the turbine and specific speed of the turbines. Thus the following are the important classification of the turbine:

1) According to the type of energy at inlet:
a) Impulse turbine
b) Reaction turbine

2) According to the direction of flow through runner:
a) Tangential flow turbine
b) Radial flow turbine
c) Axial flow turbine
d) Mixed flow turbine

3) According to the head at inlet of turbine:
a) High head turbine
b) Medium head turbine
c) Low head turbine

4) According to the specific speed of the turbine:
a) Low specific speed turbine
b) Medium specific speed turbine

Turbines can be either reaction or impulse types. The turbines type indicates the manner in which the water causes the turbine runner to rotate. Reaction turbine operates with their runners fully flooded and develops torque because of the reaction of water pressure against runner blades.

1.2 Francis Turbine

A Francis turbine has a runner with fixed buckets (vanes), usually nine or more. Water is introduction just above the runner and all around it and then falls through, causing it to spin. Beside the runner, the other major components are the scroll case, wicket gates, and draft tube.

Francis turbine is the most common water turbine in use today. They operation in a water head from 40 to 600m (130 to 2,000 if) and are primarily used for electrical power production. The electrical generations which most often use this type of turbine have a power output which generally ranges just a few kilowatts up to 800 MW through mini-hydro installations may be lower. Penstock (input pipes) diameters are between 3 and 33 feet (0.91 and 10.06 meters). The speed range of the turbine is from 75 to 1000 rpm. Wicket gates around the outside of the turbine are rotating control the rate of water flow through the turbine for different power production rates. Francis turbine is almost always mounted with the shaft vertical to isolate water from the generator. This also facilitates installation and maintenance

2. Literature review

Solar power in India is a fast developing industry. The improvements in solar thermal storage power technology is thus achieved as the cheaper solar power need not depend on cost & polluting cool .Indian turbine industry is growing rapidly as wind energy is the latest growing source of renewable energy in the country. A water turbine is a rotary machine that convert kinetic energy and potential energy of water into mechanical energy water turbine were developed in 19^{th} century & were widely used for industrial power period to electrical grids. Now they are mostly used for electrical power generation.

Manjunatha etal (2016) stated that in pelton wheel the energy gained by water is converted into kinetic energy by producing nozzle at the end of penstock. The water comes out of nozzle as jet & impinges on the bucket causing it to rotate. A pelton wheel was design which was used for micro hydro power plant. The site data of power plant was collected which includes head and water flow rate, turbine speed, turbine input power, dimensions of nozzles, runner circle diameter. The maximum turbine efficiency was then calculated. The design calculation at pelton turbine was implemented by matlab Simulink computer program. They found that pelton wheel turbine is not best turbine for low pressure streams by high flow rate & a lot of head loss occurs when discharge is low. Pelton wheel is performed in low flow rate and high head. When hydroelectric power plays an important role in future and provides maximum benefits. The pelton turbine is very easy to install for micro hydro power plants in case at high head & low flow rate.

Harendra Kumar Yadav etal (2015) stated that after the oil crisis in 1973 the world have to think about the alternative resource of energy apart from conventional energy resources (coal, gas, petroleum, etc.) so solar energy is the most important alternative resources of world & has a large potential of green energy. India has the huge potential of generating green electricity from the renewable energy sources. Efforts have been made to summarize the availability, current status & future potential at different forms of solar energy in India.

Yosuyuki Nishi etal (2014) proposed a new type of portable hydraulic turbine that uses the kinetic energy at flow in open channel. The turbine comprises a runner with an appended collection device that includes a diffuser section to improve output by catching & accelerating flow with such turbine. The performance of collection device & a composite body comprising the runner & collection device were studied. The inlet velocity ratio was most improved by collection device featuring inlet nozzle & brim. At the maximum output tip speed ratio, the inlet velocity ratio & loading co-efficient were approximately 31% & 22% higher than isolated runner,

Vishal Gupta etal (2016) stated that pelton turbine is the most commonly used high head impulse turbine with low discharge. For obtaining highest power output from runner one of the most important parameter is quality of jet which strikes bucket tangentially. The quality of jet & its impact work depends on distance between nozzle exit & runner along with its angle of strikes. They found that axial flow radially inward & output & outward flow is more for large (150mm) distance between nozzle & runner.

Catanase investigated jet form pelton turbine nozzle. They concluded that position of needle influence velocity distribution in jet. The contraction diameter of the jet & it's position are also determined mathios etdl has numerically simulated & validated impact of free jet on plate kept at various angle. Perrig al numerically experimentally analyzed flow pattern pressure distribution in pelton turbine bucket. A lot of work has been done for jet shape & simulating jet for pelton runner. In present paper commercial software ANSYS CFX used to study the effect of distance between them.

Mr. Deshmukh P.R etal (2014) stated that new technological development efficiency of solar cell is increasing every day & it is becoming cheap for use in regular day production to energy. Government is also providing help & subsides in set up of new solar power plant. Kariniotakis & stavrakasis (1995) have written extensively on simulator problems in wind generator & power grid interaction. Finally many papers have been written on electronics regulation control aspect of problem including a recent study by Neris & Co-Workers (1999) proposing on "Integrated Base Bipolar Transistor" based regulation. A number of well-known large corporation have launched initiative to generate their own energy for a variety of reasons such as reducing energy price volatility increasing security of supply decreases costs or meeting carbon objectives.

R.Sankar etal (2012) stated that solar energy is a potential next generation energy system for electrification of areas similar to ones where this project was implanted. The region can be considered as characteristics of areas where it was difficult to generate power by other means on account of higher cost. In the areas that are considerably away from grid the system can be more cost effective & practical. The high cost of establishment of grid system may be tackled by using solar energy. When the reliable electricity is found as a challenge, low cost electrification using solar energy is a very efficient method.

3. METHODOLOGY

3.1 MATERIALS

1. Solar Panel
2. Turbine
3. Centrifugal Pump
4. Penstock
5. Electric Motor
6. Nozzle

3.2 The Design Procedure of Pelton Turbine

1. Preparing the site data of power plant

This involves the calculations and measuring the net head and the water flow rate.

a. Calculation of the net head (H_n):

$H_n = H_g — H_t l = 30—6/100×30=28.2m$ (l)
Where H_g = the gross head which is the vertical distance between water surface level at the
Intake and the turbine.
H_t = total head losses due to the open channel, trash rack, intake, penstock and gate or valve.
These losses approximately equal to 6% of gross head.

b. Calculation of the water flow rate (Q):

The water flow rate can be calculated by measuring the rivet or stream flow velocity (Vr) in
(In/S) and its cross-sectional area (A,) in (m2), then: (2)
$Q = At \times h_t /60 \times 60 = \pi/4 \times D^2{}_t \times h_t /3600 = \pi/4 \times (10)^2 \times 4/3600 = 0.0873<m^3/s)$ Q)

2. Calculation of the turbine input power (Pa)

The electrical input power to the turbine in (Watt) can be calculated as:
$P_u = p \times g \times C^2{}_n \times H_n \times Q_t = 1000 \times 9.81 \times 0.982 \times 28.2 \times 0.0873 = 23.2$ (KW) (3)

3. Calculation of the turbine speed (N)

The correlation between the Specific speed (Ns) and the net head (H_n) is given for the Pelton
Turbine as H (11)
$N_s = 85.49 \times \sqrt{nj} / H^{0.243} = 85.49 \times \sqrt{2} /28.2^{0.243} = 53.7$ (4)
Wheren l= number of turbine nozzles (jets), and can be calculated as:
$nj = Q_t /Q_n = 0.0873/0.04365 = 2no$ (5)
Where Q_t = water flow capacity of each nozzle (m^3/s).
Then the turbine speed in (R.P.M) can be calculated as [l11]:
$N=N_s \times H^{5/4}{}_n / \sqrt{P_{ti}} = 5.37 \times 28.2_{1.25} / \sqrt{23.2} = 724.5$ (6)

4. Calculation of the runner circle diameter (Dr)

The water jet through nozzle has a velocity (VJ) in (m/s) can be calculated as [l l]:
$V_{tr} = C_n \times \sqrt{2 \times gH_n} = 0.98 \times \sqrt{2 \times 9.81 \times 28.2} = 23.05(m/s)$ (7)
The runner tangential velocity (V_{tr}) in (m/s) can be calculated as:
$V_{tr} = x \times Rr = \pi ND_r /60 = 10.73(m/s)$ (8)
Also the runner tangential velocity can be given as [l11]:
$V_{tr} = x \times V_j = 0.46 \times 23.05 = 10.6$ (m/S) (9)
Where x = ratio of runner tangential velocity to nozzle or jet velocity.
From equations (8) and (9):
$Dr = 60 x x /\pi N \times V_j = 0.273$ (m) (10)
At maximum efficiency the ratio of x between 0.46 to 0.47.
Then the runner diameter at maximizing efficiency can be calculated from equation (7) and (10) as:
$Dr = 38.6 \times \sqrt{H_n} / N = 38.6 \times \sqrt{28.2} /724.5 = 0.283$ m (11)
The required diameter must be greater than this calculated value due to inconsistencies in the manufacture of the buckets and the need to have a minimum distance of safety between the nozzle and the pelton runner.
If the turbine is free to rotate under no-load speed (runway speed), the runner tangential speed should be equal to the jet speed as:
$V_{tr} = w \times D_r/2 = \pi NrDr/60 = V_j$
Or
$N_r = 60 \times V_j / \pi \times Dr = 60 \times 23.05 / \pi \times 0.283 = 1255.6$ (R.P.M) (12)

5. Calculate of nozzle dimensions (11)

The water flow rate through each nozzle (Q_n) can be calculated as:
$Q_n = V_j \times A_j = 23.05 \times \pi/4 \times 0.008^2 = 0.1158$ (m^3/s) (13)
The nozzle area (A1) can be calculated as :
$A_jJ = \pi \times Dj^2 / 4 = \pi \times 0.008^2 = 0.00503$ (m^2) (14)
Then from equation (13) and (14) the nozzle diameter (Di) can be calculate as:
$D_j = \sqrt{4 \times Qt/\pi \times nj \times Vj} = \sqrt{4 \times 0.00873/\pi \times 2 \times 23.05} = 0.0491$ (m) (15)
The nozzle length can be calculated as (11):
$L_n = (D_{pn} - D_J)/ \tan\beta = 0.12{}_n - 0.0491/\tan 165 = 0.265$ (m) (16)
$D_{pm} = D_{pt}/\sqrt{nj} = 0.08/\sqrt{2} = 0.0565(m)$ (17)
The nozzle exits have to be located as close to the Pelton runner as possible to prevent the jet

Diverging the designed diameter. The distance between the nozzle and runner should be 5% of the runner circle diameter, plus an extra 3 mm clearance to account for emergency

Deflectors as:

X_{nr} = 0.05X Dr + D_t = 0.05 X 0.283 + 0.03 = 0.0004245(m) (18)

The distance between nozzle and bucket taking into account the minimum clearance between nozzle and buckets was given as:

X_{nb}= 0.625 x Dr = 0.625 X 0.283= 0.1769(m) (19)
The required distance was bigger than the calculated above, due to inconsistencies in the manufacture of buckets and the need to have a minimum distance of safety between the and Pelton runner.

6. Calculation of bucket dimensions [11]
The bucket axial width can be calculated as:
B_w = 3.4 x D_j = 3.4 x 0.0491 = 0.167011) (20)
The bucket radial length can be calculated as:
B_t = 3 x Dj = 3 x 0.0491 = 0.147(m) (21)
The bucket depth can be calculated as:
B_d = l.2 x Dj = 1.2 x 0.0491 = 0.059(m) (22)
The number of buckets in each runner must be determined 50 that no water particle was lost the minimizing the risks of detrimental interactions between the out flowing water particles and adjacent buckets. It can be calculated as:
$n_b = 15 + Dr/2\times D_j = 0.283/2\times 0.0491 = 17.88 \cong 18m$ (23)
The length of the moment arm of bucket can be calculated as:
L_{ub}= 0.195 X Dr = 0.195 X 0.283 = 0.0552(m) (24)
The runner size was determined by its diameter, and its shaper was determined by the number Of buckets. The runner shaft was sized to mount directly on the generator shaft. The flinger A Seal was also necessary to seal the whole through which the generator shall enters the turbine box. The radius of bucket center of mass to center 01' runner was given as:
R_{tr} = 0.47 x Dr = 0.47 x 0.283 = 0.133(m) (25)
The bucket volume was given as:
V_b= 0.0063 x D = 0.0063 x 0.283 = 0.000143(m3) (26)

6. Penstock design

The penstock was the piping that brings the water from the river or stream to the point where begins to be directed to the turbine. Penstock material was made of high pressure such as PVC has chosen for its availability, affordability and low friction loss characteristics he PVC was susceptible to mechanical damage from ultraviolet radiation. if the piping was weakened In an way, due to the high pressure in the penstock in any surge event, failure was a definite possibility, To prevent this, the PVC piping would be Founded in concrete along its entire length. At the bottom of penstock, before the entrance to the turbine house, a valve would be installed. This valve would allow the penstock to be emptied for turbine maintenance.

The thickness of penstock was chosen by determining the potential water hummer effect. A water hummer effect was a surge pressure that occurs when the nozzles in turbine become plugged and the flow in penstock was suddenly stopped. The thickness of penstock can be Calculated by the following relations;

$t_p = ((D_{pt} + 508 / 400)) \times 10^{-3} = 2.47\text{x}10^{-3}(m)$ (27)
$D_{pt} = 2.690\ (n^2_p \times Q_t^2\ X\ L_{pt}/H_g]^{0.1875} = 0.0252(m)$ (28)

7. Deflector Design [15, 16]

An emergency deflector system must be installed to protect the generator in case a load Circuit failure and the generator rotate at over speed.
The force in each deflector can be calculated as:
$F_d = P_w\ X\ Q_n \text{ x } V_j$ = 2012.265(N) (29)
The required force in each deflector was given as:
$F_{dr} = F_d \times$ s.f = 2012.265 x 2.5 = 5030.66 (N) (30)

8. Calculation of maximum turbine efficiency [12]

The turbine efficiency generally affected by three factors:

1. Hydraulic losses or power losses those occur due to flow irregularity within the bucket.
2. Wind age losses which occur because of resistance in the air to the move bucket.
3. Mechanical losses in the system used to transmit the power from the turbine to the Generator. If the turbine was mounted directly to the generator, there were no Mechanical losses in the turbine.

The input power to the turbine can be calculated as:
$P_n = P_w \times Q_t \times V_j^2/2$ = 23.2 (KW) (31)
The power output developed by the turbine was given as:
$P_{to} = P_w \times Q_t \times V_{tr} \times ((V_j - V_{tr})(1+\cos\varphi)$ = 22.31 (KW) (32)
Then the turbine hydraulic efficiency can be calculated as:
$n_{th} = P_{to}/P_{ti} = 2\times V_{tr} \times (V_j - V_{tr})(1+\cos\varphi)/V_j^2 = 0.9656$ = 96.56% (33)
$\varphi = 180° - \theta$
$\theta = 160° \rightarrow 170°$ (34)
For maximum hydraulic turbine efficiency
$d(n_{th})/d(V_{tr}) = 0$
Or
$V_{tr} = 0.5 \times V_j$ (35)
Then the maximum hydraulic efficiency was given as:
$N_{th}(max) = (1+ \cos(\varphi))$ = 0.97 = 97% (36)
The turbine wind age efficiency was given as:

$N_{tw} = 1 - K_d \times P_a \times A_b \times x^3 / P_w \times A_j = 0.847 = 84.7\%$ (37)

Then the total turbine efficiency was given as:
$N_{th} = n_{th} \times n_{tw} \times n_{tm} = 82.15\%$ (38)
If the turbine was mounted directly to the generator the mechanical losses can be neglected and the mechanical efficiency equal to unity.
The torque developed by the turbine can be calculated as:
$T_t = P_{to}/w = Q_t \times Dr \times (V_j - V_{tr}) = 0.292$ (N-M) (39)

3.4 Data Collected from site visit:

Type of turbine: Francis
No of Turbines: 2 no
Total Head: 142m
Gross Head: 420m
Generation Capacity: 15MW
Power Generation: 16MW
Speed of Turbine: 375 RPM

3.5 Required cost:

Energy generated from solar panel in 1 hours = 10,000 W
=10,000 × Sunshine Hours
=10,000 × 5 hrs
=50,000 w
Pump power = p = $\rho \times g \times Q \times H / 1000$
=1000×9.81×200×106 / 1000
=207972 w
X = 1.2 × 207972 × Y
50,000 = 1.2 × 207972 × Y
Y = 35 nos
Cost of one solar panel = 5,20,000 Rs
Cost of 35 nos of solar panel = 1,82,00,000 Rs
10Hp Pump: Discharge = 2, 00,000 l/day

3. CONCLUSION

After analysed and doing research on papers we have concluded and predict the result that analysing the pelton turbine with the help of 10HP centrifugal pump for suck the water from dam at certain head and giving power to that pump for starting the turbine from solar panel is not economical because it is not suitable for this site and cost of construction is high

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