ISSN XXXX XXXX © 2019 IJESC

Research Article Volume 9 Issue No.3

Hydraulic Design of Pico Hydro Power System from Sewage Water at S.S Layout, Davangere, Karnataka

Rekha. A. M[1], Amulya. T. H. M[2], Soumyashri. R[3], Raghu. G. M[4], Renuka. R[5]
Assistant Professor[1, 2, 3, 4, 5]
Department of Civil Engineering
Jain Institute Technology, Davanagere, India[1, 3, 4, 5]
R N Institute of Technology, Bengaluru, India[2]

Abstract:
The expense of hydroelectricity is moderately low, making it an aggressive wellspring of sustainable power. Diverse nations are following distinctive standards of Pico hydro running from 100 W to 5 kW that is pico hydro will be hydro power with a most extreme electrical yield of five kilowatts (5kW). Sewage based Pico hydro power plant is profoundly steady, modest and fit for creating solid power at need. In the present work the water powered design of turbine for Pico hydro power generation system has been done for the sewer line situated at S.S layout near Kalikadevi street, Davangere, Karnataka. Kaplan turbine has been chosen relying upon flow rate and net head accessible and it gives the normal water driven productivity of about 87%. The evaluated power yield from this Pico hydro power generation system is 4.86 KW. We can state that for constant guide blade angle and of the sprinter, the water powered efficiency of the Kaplan turbine will be fluctuate contingent upon vane angles.

Key words: Pico hydro power, Sewage flow, Vane angle, Guide blade angle, Specific speed, Sprinter, Kaplan turbine

1. INTRODUCTION

Hydroelectricity is power created from hydropower. In 2015 hydropower created 16.6% of the world's total power and 70% of all inexhaustible power, and was relied upon to increment about 3.1% every year for the following 25 years. Hydropower is delivered in 150 nations, with the Asia-Pacific locale creating 33 percent of worldwide hydropower in 2013. China is the biggest hydroelectricity maker. The expense of hydroelectricity is generally low, making it an aggressive wellspring of inexhaustible power. The hydro station devours no water, dissimilar to coal or gas plants.

1.1 HYDRO POWER PROJECT CLASSIFICATION

Despite the fact that distinctive nations have diverse criteria to characterize hydro power plants, a general grouping of hydro power plants is as appeared in table.

Table.1.Classification of Hydro Plant dependent on Capacity

Type	Capacity
Large	Hydro More than 100 MW and usually feeding into a large electricity grid
Medium	Hydro 15 – 100 MW usually feeding a grid
Small	Hydro 1 – 15 MW usually feeding into a grid
Mini	Hydro above 100 kW, but below 1 MW; either stand-alone schemes or more often feeding into the grid
Micro	Hydro from 5 kW up to 100 kW; usually provided power for a small community or rural industry in remote areas away from the grid
Pico	Hydro from a few hundred watts up to 5 kW

2. PICO HYDRO POWER GENERATION FROM SEWAGE WASTE WATER

Pico hydro will be hydro power with a most extreme electrical yield of five kilowatts (5kW). Hydro power systems of this size are advantageous as far as expense and effortlessness from various methodologies in the design, arranging and establishment than those which are connected to bigger hydro power. Late developments in Pico-hydro innovation have made it a monetary wellspring of intensity even in a significant number of the world's poorest and most unavailable regions. Treated water of sewage at a high pressure or flowing with a high velocity can be utilized to run turbine or water wheel coupled to Generator and in this way of electrical power is ending up increasingly more prominent as it is solid and requires minimum upkeep and care. The fundamental preferred standpoint of this power plant is a free power plant; it isn't reliant on the rainstorm in light of the fact that the accessibility of sewage water is constantly kept up. Power generation through this strategy is costlier in beginning expense however least expensive in keeps up and creation cost. Instead of releasing treated sewage emanating straightforwardly into the accepting water body, it very well may be redirected through a penstock under strain into a turbine to produce power. The treated gushing goes through a junk rack by means of a bay door into the penstock and down to the turbine, where it strikes the cutting edge and causes the shaft associated with the generator to turn, in this way changing over the rotating shaft into power. To know the power capability of water in a flow it is important to know the flow amount of water accessible from the flow (for power generation) and the accessible head. The amount of water accessible for power generation is the measure of water (in m3 or liters) which can be redirected through an intake into the pipeline (penstock) in a specific measure of time. Head is the vertical contrast in level (in meters) through which the water tumbles down. The Losses in a Hydro Plant are (a) Losses in vitality caused by flow unsettling influences at the intake to the pipeline, erosion in the pipeline, and further flow aggravations at valves and bends and (b) Loss of intensity caused by friction and design wasteful aspects in the turbine and generator.

3. APPROACH

It is important to be noticed that the water power comprises of two vital parts; specifically the head and the flow.

3.1 HEAD MEASUREMENT BY WATER-FILLED TUBE

This is the least expensive strategy for make a beeline for learn. No master gear is required. A bit of clear, plastic cylinder, around 20 meters in length with a width of 10 or 12 mm, is the fundamental device. Fill the cylinder with water so when the two finishes are held together, the water level is about 30cm from the base. The water inside the cylinder will dependably locate a similar dimension on either side. A plastic channel will pour in the water. Rises in the cylinder ought to be maintained a strategic distance from as they can cause wrong readings. They ought to be ·removed where conceivable by enabling them to ascend out of the cylinder (little air pockets don't make a difference). Somewhere around two individuals are required for this strategy yet more can help with taking estimations and recording the outcomes.

3.2 WATER FLOW RATE MEASUREMENT

Float strategy is embraced in the present investigation, the first is the cross sectional area of the sewage flow. The second is the velocity that the sewage is flowing. This is estimated utilizing a buoy and timing its movement between two points a known distance apart. At that point flow rate is determined.

4. DISTINCTIVE PARTS OF PICO HYDRO POWER GENERATION SYSTEM

Following are the parts of pico hydro power generation system.

4.1 INTAKE

Water from the variable flow is taken by the intake at a weir before redirect it into the pipelines. Ordinarily, the intake or water redirection is situated at the most elevated point in the Pico hydro system. The Points to be considered for Selection of Intake for Sewage to Treatment Process

a. Screenings
b. Settling Chamber
c. Smell control Technologies
d. Forebay Tank

4.2 PENSTOCK

Penstock is a pipeline that meant to moves the water to the turbine situated inside the powerhouse. The pipeline really has a gigantic impact to the head pressure. The more vertical drop, the more water power will center at the base of the pipeline, where the turbine is arranged.

Elements to be Consider for Selection of Penstock

1. Surface roughness & design pressure.
2. Method of jointing.
3. Weight and simplicity of establishment.
4. Availability of the site.
5. Design life and support.
6. Climate conditions.
7. Accessibility & relative expense.
8. Probability of structural damage.

Rather than penstock size, another factor should be considered is the material of the pipe. In Pico hydro plans, numerous individuals choose to utilize PVC pipe since it is exceptionally versatile, less erosion loss and hard to consumption. PVC pipe likewise simple to be introduce and the expense for the establishment is shoddy but then simple to convey all over the place.

4.2.1 PENSTOCK DESIGN

A. Utilizing ***manning's*** equation to compute the inside measurement of penstock

$$Dp = 2.69*[np^2*Q^2*L/H]^{0.1875}$$

Where, Dp = Internal dia of penstock in m.
np = Manning's coefficient of material.
L = Length of penstock in m.
Hg = Gross head in m.
Q = Discharge in m^3/sec.

B. Least divider thickness of penstock, tp = (Dp+508)/400 +1.2

C. Velocity in penstock (v), V = Discharge/(Area of Penstock)

D. Loss due to friction by Darcy's Weisbach Equation, $hf = (4fLV^2)/2gd$

Where, hf = Loss because of friction in m.
f = Friction coefficient.
L = Length of penstock in m.
V = Velocity of penstock in m/sec.
d = Diameter of penstock in m.

E. Net Head in Penstock (H)

The other head losss (h_0) at specials contains intake loss (h_i), gate/valve loss (h_g), bend loss (h_b), bi/trifurcation loss (h_y), inlet valve loss (h_g) and transition piece loss (h_{tr}). Every one of these losses are accepted as 5% of the gross head. The total head loss (h) can be acquired according to condition, $h = h_f + h_0$
Net head = Gross head – total head loss

4.3 NOZZLES

A nozzle is a pipe or tube of changing cross sectional area and it tends to be utilized to coordinate or adjust the flow of a liquid (fluid or gas). Spouts are much of the time used to power the rate of flow, velocity, course, mass, shape, as well as the weight of the flow that rises up out of them. In a nozzle, the velocity of liquid increases to the detriment of its pressure energy.

4.4 TURBINE

Turbine is the principle parts in the Pico hydro system, where the errand is to transition over water capacity to rotational power so as to drive the generator. It is imperative to choose the correct turbine as a large portion of the losses are because of this segment.

4.4.1 CHOOSING OF TURBINE

Regularly, choosing hydro turbines depends on the explicit velocity of the turbine, a no dimensional parameter that incorporates head, yield power and yield shaft velocity. The Pico extend, under 5 kW generations, gives off an impression of being scantily secured by announced application spaces. There are a few industrially accessible Pico hydro items at high, mid and low head, and these will in general pursue the topology of the bigger scale turbines.

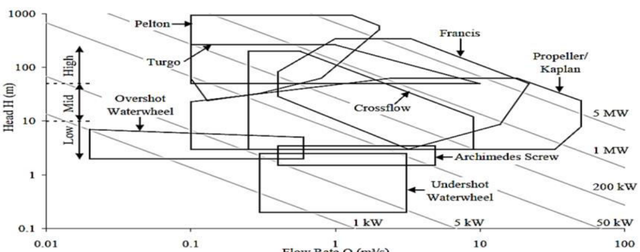

Figure.1. Selection of turbine

4.4.2 TURBINE DESIGN

For picking the nozzle diameter to ascertain the velocity of jet V_1 in m/sec

Velocity of jet (V_1) = Discharge/area of nozzle

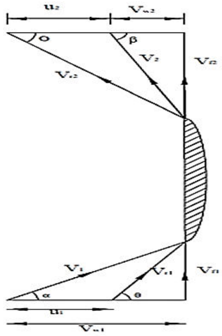

Figure.2. Velocity Triangle for Kaplan Turbine

Where,

V_1 = Velocity of the jet at inlet.

u_1 = Velocity of the plate (vane) at inlet.

V_{r1} = Relative velocity of jet and plate at inlet.

α = Angle between the direction of the jet and direction of motion of the plate, also called guide blade angle.

θ = Angle made by the relative velocity (V_{r2}) with the direction of motion at inlet also called vane angle at inlet.

V_{w1} and V_{f1} = The components of the velocity of the jet V_1, in the direction of motion and perpendicular to the direction of motion of the vane respectively.

V_{w1} = It is also known as velocity of whirl at inlet.

V_{f1} = It is also known as velocity of flow at inlet.

V_2 = Velocity of the jet, leaving the vane or velocity of jet at outlet of the vane.

u_2 = Velocity of the vane at outlet.

V_{r2} = Relative velocity of the jet with respect to the vane at outlet.

β = Angle made by the velocity V2 with the direction of motion of the vane at outlet.

ϕ = Angle made by the relative velocity Vr2 with the direction of motion of the vane at outlet and also called vane angle at outlet.

V_{w1} and V_{f1}= Component of the velocity V2, in the direction of motion of vane are perpendicular to the direction of vane at outlet.

Computation Vane Angles and Guide Blade Angles

From **velocity inlet triangle**

- Compute the velocity of flow at inlet, $V_{f1} = \sin\alpha * V_1$
- Compute the area of inlet, $Q = \pi/4*[D_0^2 - D_b^2]*V_{f1}$ (where $Db = 1/3*D_0$)
- The peripheral velocity at inlet and outlet are equivalent, $u_1 = (\pi*Do*N)/60$
- Compute the velocity of whirl at inlet, $V_{w1} = V_{f1}/\tan\alpha$
- Compute the vane angle at inlet, $\theta = \tan\text{-}1(V_{f1}/(V_{w2} - u_1))$
- Compute the relative velocity of jet and plate at inlet, $V_{r1} = V_{f1}/\sin\theta$
- Compute the vane angle at outlet, $\phi = \cos^{-1}((u_2+V_{w2})/V_{r2})$
- Hydraulic efficiency (η_h) = $((V_{w1}*u_1)\text{-} (V_{w2}*u_2))/gh$

4.5 GENERATOR

Generator is a machine used to transitions over the rotational vitality from water turbine into power and at this generation; there will be a decrease in proficiency. Be that as it may, with encouraging the cutting edge innovation, well-fabricated generators convey great proficiency. Producing system for a hydro power plot is chosen dependent on the assessed intensity of a hydropower system, sort of supply system and electrical load, accessible creating limit in the market and generator with financially savvy.

Figure.3. Pico Hydro Generators

Induction generators and synchronous generators deliver AC power. Enlistment generators are favored in remote regions since they are vigorous and entirely dependable. An electronic power associated with out of generator matches power created to the heaps so as to keep the volt generation going here and there.

5. LOCATION OF STUDY AREA

The hydraulic design of turbine for Pico hydro power generation system has been completed for the sewer line situated at S.S layout near Kalikadevi Street, Davangere with longitude 75.920 E scope 14.460 N which is 602.5m (1977ft) from mean ocean level. The month to month normal yearly precipitation of 644mm of Davangere for the time of 2013-2016 was taken for undertaking reason.

Highlights of Sewer Line

The sewer line referenced in above area is Rectangular sort of sewer and Breadth of sewer is 3.15m and Depth of sewer is 2m with flow profundity during dry period is 0.2m.

6. RESULTS AND DISCUSSIONS

Area of flow A is 0.62 m2 and average velocity V by using float method is 0.41m/sec.

By using the continuity equation, rate of flow,

Q = AV = 0.62*0.41

Q = 0.25m3/sec.

Penstock Design: For choosing the penstock material as PVC pipes, Using manning's formula internal diameter of penstock Dp obtained is 0.40m, Minimum wall thickness of penstock tp is

3.50m, Velocity in penstock V is 2m/sec, Loss due to friction by Darcy's Weisbach Equation hf is 0.1076m. Assuming 5% of other loss, Net head H is 2.28m.

Input power $P = Q \times H \times g = 0.25 * 2.28*9.81$
$P = 5.59$ KW

Turbine Design: For 2.5m head and 0.25m3/sec discharge the turbine selected is "Kaplan turbine". Considering nozzle diameter as 0.15m then V1 = 14.15m/sec. For trial and error method for choosing: Guide blade angle (α) = 350 Specific velocity (N) = 270 r.p.m and

From velocity inlet triangle, Vf1 = Vf2 = 8.12 m/sec, D0 = 0.21m, Db = 0.07m, u1 = 2.96 m/sec, Vw1 = 11.6m/sec, θ = 43013', Vr1 = 11.85 m/sec, ϕ = 470 391 and ηh = 0.87 = 87%. For different trails of choosing different guide blade angle (α) & specific velocity (N) as to get minimum efficiency of 85%, the values obtained are listed below in table 5.4.3

Output Power: P = Q*h*g*η
By taking average efficiency η = 87%
$P = 0.25*2.28 *9.81*0.87$
$P = 4.86$ KW

7. DISCUSSION

Table Variation of hydraulic efficiency with Different Guide Blade Angle and Specific Velocity

Guide blade angle (α)	Specific velocity (N) rpm	(θ)	(ϕ)	Hydraulic efficiency (η_h)
$\alpha_1 = 30^0$	$N_1 = 300$	39^0	25^0	85%
			27^0	87%
			30^0	90%
$\alpha_2 = 35^0$	$N_2 = 270$	43^0	46^0	85%
			47^0	87%
			50^0	90%
$\alpha_3 = 40^0$	$N_3 = 250$	48^0	60^0	85%
			57^0	87%
			48^0	90%

If further increases in α and θ and decrease in N then ϕ should be correspondingly decreased for obtaining increasing efficiency.

1. Output power for an aver generation efficiency is 87% = 4.86 KW
2. For α = 30º, N = 300 rpm, θ = 39º, Efficiency will be varies from 85% to 90%, ϕ increases from 25º to 30º.
3. For α = 35º, N = 270 rpm, θ = 43º, Efficiency will be varies from 85% to 90%, ϕ increases from 46º to 50º.
4. For α = 40º, N = 250 rpm, θ = 48º, Efficiency will be varies from 85% to 90%, ϕ decreases from 60º to 48º.

If further increases in α and θ and decrease in N then ϕ should be correspondingly decreased for obtaining increasing efficiency.

8. CONCLUSION

1. Pico hydro can be a suitable solution to improving rural electrification and has been applied only in a few instances for medium to high head application.
2. The Pico hydro system open up new opportunities for some isolated communities in need of electricity. With only a small flow needed, remote areas can access lighting and communications.
3. Sewage based Pico hydro power plant is highly stable, cheap and capable of producing reliable power at need because the head/pressure of the sewage reservoir has been maintained at constant head.
4. Sewage based hydro power plant has recommended for supply to local farmers for irrigation purpose after proper chemical treatment of the water and generation of the electrical energy.
5. For constant value of guide blade angle and constant specific velocity of the runner, the hydraulic efficiency of the Kaplan turbine will be vary depending on vane angles.
6. The actual power output from this Pico hydro power generation plant is 4.86 KW

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