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SEWAGE TURBINE: -HYDROPOWER OPPORTUNITIES FROM TREATED SEWAGE WATER

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Abstract:
Increased Urban migration is one of the principal causes of the generation and discharge of enormous volumes of both domestic and industrial Wastewater. This has led to the establishment of a large number of Treatment units over the last decade, which gives the reprocess of water and ensures basic sanitation in society. Every human activity in progress, it's leading to a considerable threat to our environment.
Wastewater treatment uses a lot of energy and accounts for nearly a quarter of total power consumption. As a result, finding a cost-effective and long-term alternative to reduce reliance on fossil fuels and thus harmful carbon emissions is critical.
The purpose of this research is to show how a micro hydropower plant (MHPP) can be used to supply some of the increasing electricity demands. MHPP in S.T.P is not a new concept; it has been used in many countries. The paper outlines some of the advantages and disadvantages of installing a micro-hydro power plant in S.T.P along with the components required in an MHPP. The paper showcases a theoretical case study in which MHPP has been installed in one of the S.T.P's in D.Y. Patil College of Engineering, Akurdi, Pune Based on the flow and head available, a specific turbine is selected and the respective design is discussed. Results showcased that this methodology can produce 72445 units annually, while the return-on-investment period is 1 year. A high benefit-cost ratio of 2.24 is observed. It can be concluded that MHPP is an efficient and renewable source for energy generation and the implementation of this technology is expected to increase in the coming future.
Keywords: - Micro- Hydropower, Sewage Treatment Plant, Kaplan Turbine

I. INTRODUCTION

Kaplan Turbine:
The Kaplan turbine is an axial reaction flow turbine with adjustable blades. Axial flow turbines are those that have water flowing parallel to the shaft's rotation axis.

For low heads and relatively large discharges, Kaplan turbines have become the most widely used type of turbine. Kaplan turbines have been developed to be the most employed type of turbines for low heads and comparatively large discharges. The Kaplan turbines are fairly suitable for the purpose for three main reasons:

(1) relatively small dimensions combined with high rotational speed
(2) A favorable progress of the efficiency curve
(3) large overloading capacity

- Main Components of Kaplan Turbine: -
  - Scroll casing,
  - Guide vane mechanism,
  - Hub with vanes or runner of the turbine, and
  - Draft tube.

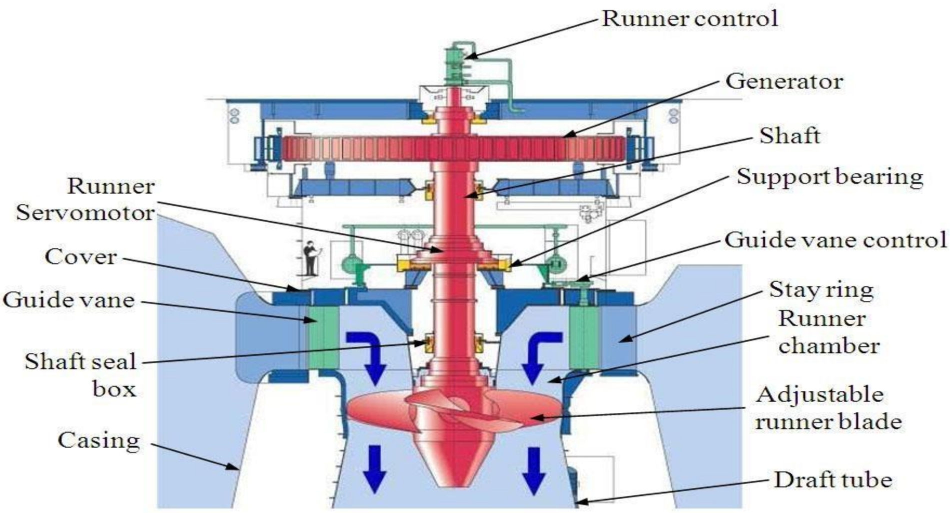


Fig1. Complete Assembly of Kaplan Turbine

- Scroll casing:

a) The scroll casing is a spiral casing with a smaller cross-sectional area. Water from the penstocks first enters the scroll casing before moving on to the guide vanes.
b) The water flows axially through the runner after turning 90 degrees from the guide vanes.
c) The scroll casing protects the turbine's runner, runner blades, guide vanes, and other internal components from external damage.

- Guide Vanes Mechanism:
  a) This is the only part of the turbine that controls how it opens and closes in response to the demand for power.
  b) When more power is required, it opens wider to allow more water to strike the rotor blades.
  c) When low power output is required, it closes to stop the water flow.
  d) When the guide vanes are missing, the turbine cannot work efficiently, and the turbine's efficiency suffers.
- Hub with vanes or Runner of the turbine:
  a) In the Kaplan turbine, the term "Runner" is very important. The runner is the turbine's rotating component that aids in the generation of electricity. The shaft is connected to the generator's shaft.
  b) This turbine's runner has a large boss on which the blades are attached, and the runner's blades can be adjusted to the best angle of attack for maximum power output. The Kaplan turbine's blades twist along their length.
  c) The Kaplan turbine has twist along its length in order to maintain the optimum angle of strike for all cross-sections of blades and thus increase the turbine's efficiency.

The term "Runner" in the Kaplan turbine plays an important role. The runner is the rotating part of the turbine in which helps in the production of electricity. The shaft is connected to the shaft of the generator.
The runner of this turbine has a large boss on which its blades are attached and the blades of the runner are adjustable to an optimum angle of attack for maximum power output. The blades of the Kaplan turbine have twist along its length.
Twist along its length in the Kaplan turbine is provided because to have always the optimum angle of strike for all cross-section of blades and hence to achieve greater efficiency of the turbine.

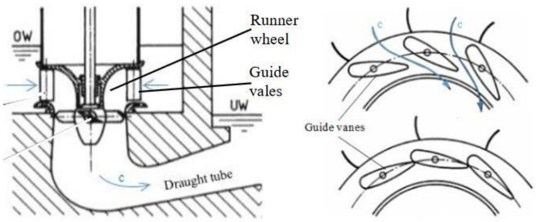


Fig. 2: A Kaplan turbine (runner wheel and guide vanes).

- Draft Tube:

The pressure available at the exit of the Reaction Turbine's runner is typically less than atmospheric pressure. Water at the exit cannot be discharged directly into the tailrace. Water is discharged from the turbine exit to the tailrace through a tube or pipe that gradually increases in area.

➢ Advantages of the Kaplan Turbine:

- This turbine work more efficiently at low water head and high flow rates as compared with other turbines.
- This is smaller in size.
- The efficiency of the Kaplan turbine is very high as compared with other types of hydraulic turbines.

- The Kaplan turbine is easy to construct and
- The space requirement is less.

➢ Disadvantages of Kaplan Turbine:

- The position of the shaft is only in the vertical direction.
- A large flow rate must be required.
- The cavitation process is the most significant disadvantage. Due to pressure drops in the draught tube, this occurs.
- The use of the draft tube and proper material generally stainless steel for the runner blades may reduce the cavitation problem to a greater extent.

II.AIM & OBJECTIVE OF WORK:-

The research areas to date have been restricted to Micro Hydropower Generation using Treated Wastewater. A sincere attempt has been made to study possible opportunities for Micro Hydropower generation from treated wastewater, with the following research carried out:

1. To study the hydraulic parameters at the existing sewage treatment plant considered for the study.
2. To design a suitable sewage hydropower system for Micro hydropower generation.
3. To determine characteristics of the hydropower system such as discharge, head, power efficiency, pressure, and unit parameters.
4. To estimate the hydropower that can be generated and the associated economics

III. METHODOLOGY ADOPTED FOR STUDY:-

The general methodology adopted to determine the possibilities for hydropower generation from treated wastewater included a selection of a potential site with appropriate discharge. After identification of the source, Discharge-time studies were conducted for a certain duration. With the obtained parameters, the Design of the Kaplan Turbine and other components of the system was carried out. Based on power output feasibility of the project was determined such as power generated per year, Benefit-cost ratio, payback period

IV. Selection of Wastewater Treatment Plant:-

DR. DY PATIL COLLEGE OF ENGINEERING, AKURDI has its very own Secondary Wastewater Treatment Plant that serves for the treatment of institutional water and stormwater. The process design involves the physical and biological processes, treatment capacity of 18000 liters capacity

V. DESIGN OF KAPLAN TURBINE:-

- **Hydroelectric potential is calculated as:**

$P = \lceil QH\eta\rho g$ ………… (1)

Where: ρ= Density of water (1250 kg/m^3)

Q= Design Discharge

H= head Available at the site = 1.5 m

η = Efficiency of the turbine = 0.90

Therefore, Design discharge power required for generation of 8000 watts will be:-

$Q = \frac{P}{\rho \eta g H}$

Q= 0.48 m^3/sec

- Specific Speed (Ns) = 885.5/ H^0.25 = 800.13≈800 rpm

- Speed of the turbine (N) = NsH^1.25/√P = 1386.11rpm

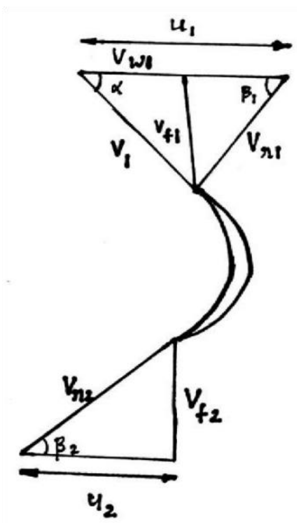
- Periphery Co-efficient (Ǿ) = 0.0242×800.13^2/3= 2.08

- Runner Diameter (Dr)= $\frac{84.5\times Ǿ\times\sqrt{H}}{N}$ = 0.69m

- Hub Diameter (Di) = 0.41 × Dr = 0.282m

- Power Developed by the turbine (Pt)= 1250×0.9×1.5×0.5= 0.8435watts

- Area = $\frac{\pi(D^2-d^2)}{4}$ = 0.311 m^2
- Flow Velocity (Vf) = $\varphi\times\sqrt{2gh} = 3.79\ m/s$



Guide Vane Design:

$U^1 = \frac{\pi\times D\times N}{60}$ = 11.12 m/s

Similarly,

U_2 = 4.546 m/s ά = 72.56°

V_{f1}= 3.79 m/s $_{\beta}1$ = 20.89 °

V_{f2} = 9.26 m/s $_{\beta}2$= 39.81°

V_1= 3.97 m/s

V_{w1} = 1.19 m/s

V_{r1}= 10.62 m/s

V_{r2}= 5.91m/s

- Length of Guide blades :-

$L = \frac{1.5\frac{D}{2}-\frac{d}{2}}{sin\alpha}$ = 0.320 m

B=0.41…………. (Q=A×V×f)

- Draft Tube:

T= D = 0.69 m

Y= 3D = 2.07m

- Outlet Diameter(D_d)

= D+ 2 (tan 17.44°×0.147)

= 1.99m

- No of blade (z) = $\frac{1}{4}\times\sqrt{D}+5 = 5\ Nos$

- **Design of Blade Profile:**

1. R1 = $\frac{d}{2}$ +0.015D = 0.29m
2. R5 = $\frac{D}{2}$ -0.015D = 0.33m
3. R3 = $\frac{D}{2} \times \sqrt{1 + \frac{Dd^2}{2}}$ =0.349m
4. R4 = R3 +$\frac{R5-R3}{2}$ = 0.339m
5. R2 = R1+$\frac{R3-R1}{2}$ =0.319m

- Blade Spacing:-

T = $\frac{2\pi r}{4} = \frac{2\times\pi\times0.3254}{4} = 0.5$m
Circulation $\tau = 2\pi rcu1$ = 2.43 m/s

- **The Power generated for a day will be (P)**

Consider operating time 24hrs = Ƞ×ρ×g×Q×H
=198.48 KWD
For the complete year (P) = 198.48×365
= 72445.2 kWh
If the average cost of 1KW in INDIA is Rs. 5 / kWh
Energy Savings per year = 72445.2× 5
= 36226 Rs

- **Estimation of Project Cost**

Cost of Kaplan turbine = 4,60,000
Intake structure and Penstock = 25,000/-
Power House = 70000/-
Total Expenses = 5,55,000

Assumptions from another micro hydropower project.

1) Operation cost = 20% of total cost
2) Maintains cost -- 0.5% of civil work cost
2% of Hydro mechanical electrical cost
3) Annual depreciation charges = 2% total cost
4) Life of project 20 Year after commencement
5) Duration of project 1 year completion

1) Operation cost = 0. 2×95000 = Rs 19000

2) Malignance Cost

a) 10% of civil structure cost 0 .1 × 95,000= 9500
b) Depreciation charges = 0.02 × 95000 = 1900
c) Interest charges = 0.1×95000 = 9500
d) Miscellaneous Incidental charges = 0.02 × 95000 =1900

Therefore, total annual expense **Rs. 32300**

Consider 10% losses in the transmission and other losses of energy
Annual revenue = Total units × selling price per unit
= 123187.5× 5 = 615937
Benefit cost Ratio = annual revenue / annual expenses
= 72445.2/32300
= 2.24
Pay Back Period = Total investment cost /Savings per year
= 587300/615937
=0.95 ≈ 1 year

TABLE 1 RESULT DATA OF MAIN CHARACTERISTICS

Parameter	Symbol	Value	Unit
1. Power	P	8.27	Mw
2. Gross Head	H	1.5	m
3. Hydraulic Efficiency	η_h	0.9	-
4. Flow Rate	Q	0.5	m^3/s
5. Net Head	Ha	1.35	m
6. Specific Speed	Ns	800.13	rpm
7. Runner Speed	N	307.91	rpm
8. Flow Speed	φ	0.7	-
9. Velocity of Flow	Vf	3.79	m/s
10. Whirl velocity	Vw	1.19	m/s
11. Runner Diameter	Dr	0.69	m
12. Hub Diameter	Di	0.282	m
13. Number of runner blades	Ng	5	Nos
14. Length of guide vane	L	0.320	m
15. Height of guide vane	B	0.41	m
16. Guide vane inlet angle	$\alpha 1$	72.56°	-
17. Runner inlet angle	β1	20.89°	-
18. Runner outlet angle	β2	24.77°	-
19. Water Circulation	τ	2.4	m^2/s

VI. CONCLUSION:-

Engineers are known to make things simple and it is only possible if they themselves have analyzed every concept and are able to apply it in the real world.

In this paper, we have presented a detailed assessment of hydropower generation from treated sewage water using a Kaplan turbine. Installing a micro-hydro power plant in the sewage treatment plant is a very useful concept because electricity generated from the turbine is going to use for the working of the sewage treatment plant. The cost of installation is Rs. 5,55,000. The cost-benefit ratio is 2.24 whereas the payback period is 1 year approximately. The Installation of this concept will also result in annual savings of Rs.615937. Thus it is concluded micro hydropower plants are a renewable, efficient and environmental friendly solution.

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