"FEASIBILITY STUDY ON POWER GENERATION USING TREATED WASTE WATER"

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Abstract - *Municipal waste water is an alternative Source for micro hydro power generation. Today waste water treatment plants are usually the facilities with the highest energy demand in public ownership. Thus, renewable energy facilities are added in order to reduce the overall demand of energy supply taken from the power grid. Consequently micro hydro power plants are part of this strategy, using new identified site for micro hydro power implementations. The work analysis of hydro power generation at Kesare treatment plant summarizes the selection for suitable turbine using Chart of commercially available turbines as per IS 12800(part3):1991, cross flow turbine was selected but due to topographical and other restrictions floating rotor turbine was considered. The design of floating rotor turbine is based on vertical axis wind turbine (H-rotor} and fabrication is on trial basis to study the performance of turbine at study area. But the difficulty in measuring the power led to use in direct method. Using dimension analysis and linear regression analysis it was found that rotor swimming turbine is capable of producing 232W in horizontal shaft condition and 0.77W in vertical shaft condition.*

***Key Words*: Municipal wastewater, Micro hydropower, Floating turbine, Air foil blades, vertical shaft, and horizontal shaft**

1. INTRODUCTION

Energy requirements have been increasing exponentially worldwide. At present global energy requirements are mostly dependent on fossil fuels, which will eventually lead to an exhaustion of limited fossil energy sources. Combustion of fossil fuels also has serious negative effect on the environment due to carbon dioxide emission, which could be the main reason for climate change. Electricity is one of the most important resources that the science has given to mankind. It has also become a part of modern life. In present scenario power infrastructure in India is not capable of providing sufficient and reliable power supply. Some 400 million people have zero access to electricity which is due to lack of resources. Electricity can be generated using both conventional and non-conventional sources of energy such as solar energy, nuclear energy, hydropower energy, biomass energy and wind energy. But these energy sources require more space for installation and are also expensive. These sources of energy may also harm the environment. In the last decade, problems related to energy crisis such as oil crisis, climatic change and electrical demand have raised world-wide. These difficulties are continuously increasing, which suggest the need of technical alterative to assure the solution. One of these technological alternatives is generating electricity as near as possible of the consumption site, using the renewable energy sources such as wind, solar, tidal and hydro-electric power. Hydro-electric power is a form of renewable energy resources, which comes from the flowing water. The net head available to the turbine indicates the selection of type of turbine suitable for particular site. There are many alternative techniques used for generating electricity from wastewater treatment plant such as up flow anaerobic sludge blanket (UASB) and Microbial fuel cell (MFC), UASB has certain disadvantages such as bad odour and start up require quite long time and also MFC has many limitations like low power density high initial cost, activation loss, bacterial metabolic losses.

1.1 Objective

The main objective of this research work is feasibility study on micro hydropower generation at Kesare wastewater treatment plant.

Specific Objective

- Conduction of profile survey to ascertain the available head
- To select a suitable turbine
- To design and fabricate the turbine
- To assess the performance characteristics of turbine at pilot scale

1.2 Literature Review

Water and wastewater treatment processes are energy intensive accounting for around 30 to 80% of the industry production cost. Given this background, the journal "**Hydropower Opportunities in the Water Industry**" by Theophilus Gaius-obaseki discussed about sustainable and cost effective ways of producing energy to reduce its dependence on fossil fuel for energy generation, reduce the carbon emissions, ensure the security of its power supply and energy cost. Addressing the problem of energy sustainability in the water and wastewater industry thus requires a thorough review and research into technologies that are cost effective and sustainable for each location. The industry thus needs to harness renewable and non-polluting resources that are at its doorstep like micro-hydropower.

This paper gives an overview of hydropower application options available to the water and wastewater treatment industry. With the help of hydropower theory, author explained about classification of hydropower, type of turbine selected for power generation in United Kingdom. From this paper, author concludes that hydropower is proven and generally predictable source of renewable energy and is one of the few that is not intermittent. Noise is one of the disadvantages and is minimized by adequate acoustic installation.

Today WWTPs are usually the facilities with the highest energy demand in public ownership. Thus, renewable energy facilities are added in order to reduce the overall demand of energy supply taken from the power grid. Consequently also small hydropower plants are part of this strategy, using new identified site for small hydropower implementations. This paper gives an overview of the approaches so far, suitable technique as well as restrictions which have to be considered for an operation of small hydropower concepts for energy recovery and storage. With the help of a case study on communal WWTP (emscher sewer, Germany) and other sewer system author explained about the recovery and storage facilities." **Advanced energy recovery strategies for wastewater treatment plants and sewer systems using small hydropower**" by V. Berger and team concludes that if suitable discharges and heads are available, hydropower is the simple and economic way to enhance the self-energy production and thereby saving energy costs as well as improving the operator's carbon footprint.

"**Micro Hydro Installation Analysis in a Wastewater Treatment Plant**" by H. Beltran and team, introduce the technical and economic viability of a new micro hydro installation solution to reduce the power consumption of a medium sized wastewater treatment plant. The work analyses the hydroelectric potential of the plant and summarizes the turbine generator design procedure performed to optimize the production. Water turbines are classified into two different groups: impulse turbine and reaction turbine. The first group, which mainly includes Pelton, Turgoand Crossflow, works changing the velocity of water jet. The water is accelerated prior to enter the turbine using its own pressure but, once the water is flowing over the turbine runner blades the pressure is constant and all the work output is due to the change in kinetic energy of water. Conversely, reaction turbine such as Francis or Kaplan types base their functioning on the change of pressure experienced by the water as it moves through the turbine and gives up its energy. Impulse turbines are more frequently used for high head sites, while reaction turbines are usually used for low head sites. The analysis of the results shows that an acceptable power production can be obtained by introducing the proposed installation.

Micro hydroelectric power is both an efficient and reliable form of clean source of renewable energy. It can be an excellent method of harvesting renewable energy from small rivers and streams. The choice of turbine depends mainly on the pressure head available and flow rate. Design considerations for micro hydroelectric power plants are flow duration curve, flow rate measurement, trash rack design, head measurement, turbine power, turbine speed and turbine selection. There are two basic modes of operation for hydro power turbines: Impulse and reaction. Impulse turbines are driven by a jet of water and they are suitable for high heads and low flow rates. Reaction turbines are filled with water and use both angular and linear momentum of the flowing water to run the rotor and they are used for medium and low heads and high flow rates. Micro hydro power installations are usually run-of-river systems, which do not require a dam and are installed on the water flow available on a year round basis. Above considerations are explained by Bilal Abdullah Nasir in his journal **"Design Considerations of Micro-Hydro-Electric Power Plant"**.

Hydraulic turbine can be defined as a rotary machine, which uses the potential and kinetic energy of water and converts it into useful mechanical energy. According to the way of energy transfer, there are two types of hydraulic turbines viz., impulse turbines and reaction turbines. Pelton turbine comes under impulse turbine which performs in high head and low water flow, in establishment of micro hydroelectric power plant, due to its simple construction and ease of manufacturing. To obtain a pelton hydraulic turbine with maximum efficiency during various operation conditions, Bilal Abdullah Nasir in his paper "**Design of High Efficiency Pelton Turbine for Micro Hydropower Plant**" considers various parameter which includes turbine power, turbine torque, runner diameter, runner length, runner speed, bucket dimensions, number of buckets, nozzle dimension and turbine specific speed. The complete design of turbine has been presented in this paper based on theoretical analysis and some empirical relations. The maximum efficiency was found to be 97% constant for different values of head and water flow rate.

The aerodynamic Airfoils of wind turbine blades have crucial influence on aerodynamic efficiency of wind turbine. This involves the selection of a suitable Airfoil section for the proposed wind turbine blade. Lift and Drag forces along with the angle of attack are the important parameters in a wind turbine system. These parameters decide the efficiency of the wind turbine. In this paper an attempt is made to study the Lift and Drag forces in a wind turbine blade for NACA0012, NACA4412 & NACA0018 Airfoil profile is considered for analysis. **An Analysis of Lift and Drag Forces of NACA Airfoils Using Python** by Tarun B Patel, in his study explains, airfoils are structures with specific geometric shapes that are used to generate mechanical forces due to the relative motion of the Airfoil and a surrounding fluid. Wind turbine blades use Airfoils to develop mechanical power. The cross-sections of wind turbine blades have the shape of Airfoils. The width and length of the blade are functions of the desired aerodynamic. The NACA Airfoils are Airfoil shapes for aircraft wings developed by the National Advisory Committee for Aeronautics (NACA). The shape of the NACA Airfoils is described using a series of digits following the word "NACA". The parameters in the numerical code can be entered into equations to precisely generate the cross-section of the Airfoil and calculate its properties.

In recent years the Darrieus wind turbine concept has been adapted for use in water, either as a hydrokinetic turbine converting the kinetic energy of a moving fluid in open flow like an underwater wind turbine, or in a low head or ducted arrangement where flow is confined, stream tube expansion is controlled and efficiency is not subject to the Betz limit. Performance prediction models are valuable tools for use in the development of tidal turbines. A model that can accurately predict the performance of a device can be used to optimize the design parameters more rapidly and at a much lower cost than carrying out the design studies using scale model tests. Hydro dynamic model for darrieus turbine is simple prediction of coefficient of performance of rotor. Time require for calculation is less. "**Hydrodynamic Modeling of Straight Blade Darrieus Turbine**" by H.S.Chaudhari, the model is capable of predict the effect of rotor solidity on the performance of turbine. This model always predicts higher power than the experimental results. It does not predict the water velocity variations across the rotor. These variations gradually increase with the increase of the blade solidity and tip speed ratio. Hydro dynamic model does not take into account the difference in the induced velocities between the upstream and downstream halves of the rotor or any difference in velocities across the rotor such as those due to water shear. The main drawback of these models is that they become invalid for large tip speed ratios and also for high rotor solidities because the momentum equations in these particularcases are inadequate.

Generation of electricity in a cheap and efficient manner is the primary goal of every country. Each power generating company tries to develop the best suitable method to generate electricity and renewable have become the primary source of power generation with the rapid consumption of conventional fuel. Hydropower, large and small, remains by far the most important of the "renewable" for electrical power production worldwide, providing 19% of the planet's electricity. The revolution in cross flow turbine industry came when the straight blades of the Darrieus turbine were modified into helical shape by Alexander M. Gorlov. There have been several research projects dealing with the design and analysis for tidal applications. This paper deals with the design and analysis of a cross flow hydrokinetic turbine (CFHT) with helical blades. Static analysis with optimum blade velocity and constant pressure conditions was performed for the blade with fixed pitch by using Computational Fluid Dynamics.**"Design and Analysis of a Cross Flow Hydrokinetic Turbine Using Computational Fluid Dynamics"** byHimanshu Joshicarried3D modeling of the turbine. The hydrofoil shape of NACA 0018 was created by the airfoil coordinate database.

Micro hydropelton turbine design considerations are(**Bilal Abdullah Nasir,2014**) power, torque, runner diameter, runner length, runner speed, bucket dimensions, number of buckets, nozzle dimension and turbine specific speed and in case of vertical axis hydrokinetic wind turbine (**Vlado Halusek,2012**)location, speed and depth of the water flow were considered. From section 2.5 straight bladed darrieus turbine can be used for different materials and dimensions. Compared to other airfoil shapes NACA0018(**Tarun B Patel**, **2015**) is less stall susceptible.

From the literature it can be concluded that head, power, speed, velocity of flow, material and location are the important design parameters. The advantages of NACA0018 are considered and used in this research work.

2. Methodology

In this work the first step is to select study area, before installation of micro hydro power generation turbine. The profile survey has to be done near Kesare waste water treatment plant, Mysuru District, Shown in Figure 2. This is the study area which will be selected for project. The details of study area are shown in Table 1. The waste water samples were collected at 3 locations inlet, aeration and outlet of Kesare waste water treatment plant as shown in Figure 1. The velocity is determined at selected locations, using indirect method (Ball and stop watch) as shown in Figure 3, as suitable equipment was not available. Laboratory analysis is done for collected samples to know P^H, Acidity and alkalinity parameters to check whether it affects the blades of the turbine or not. Based on the turbine selection chart it is identified that cross flow turbine and Kaplan turbine are suitable. But these two turbines are high cost and make noise pollution; also it has to be fixed in one place. To overcome these disadvantages an alternative turbine has been chosen i.e Rotor swimming Turbine. The turbine components are identified based on the design criteria and analysis. The micro hydropower generation turbine has been Prepared, testing of turbine is done and performance test is conducted. The power equation is generalized using Dimensional Analysis and Multi linear Regression Analysis. The Rotor swimming turbine is showing in Figure 4

Table-1: Study area details.

Study area	Kesare wastewater treatment plant
Latitude and longitude	12°21'04"N ,76°39'54.4"E
Design capacity	30MLD
Number of lagoons	2
Number of aerators	12 in each lagoon

Number of sedimentation tanks	2
Disposal point	Nearby valley out of which some part is used for agricultural purpose

Classification of small scale hydropower capacities in KW is shown in Table-2

Fig-1: Sample Collection at Kesare wastewater treatment plant

Fig-2: Profile survey at study area

Fig-3: Velocity measurement at sampling point

Table-2: Classification of small scale hydropower

Type	Station capacity	Unit capacity
Micro-hydro	Up to 100 kW	Up to 100 kW
Mini-hydro	101 to 2000 kW	101 to 1000 kW
Small-hydro	2001 to 25000 kW	1001 to 50000 kW

3. RESULT AND DISCUSSION

Rotor swimming turbine is prepared based on the design considerations and analysis. The tests of the sample of three locations inlet, aeration and outlet are given in Table1.
Tests of P^H and acidity, alkalinity are done and sample details are given in Table3. These tests are important because it affects the blades of the turbine. The longitudinal section of Kesare waste water treatment plant is shown in Figure 5. This was obtained from profile survey. In this profile survey for every fixed chainage RL was measured, using this RL of Fixed Chainage longitudinal section was drawn. The rotor swimming turbine is designed based on the vertical axis wind turbine. By keeping the chord length and number of blades constant the height of the vane was reduced from 0.4m to 0.3m.

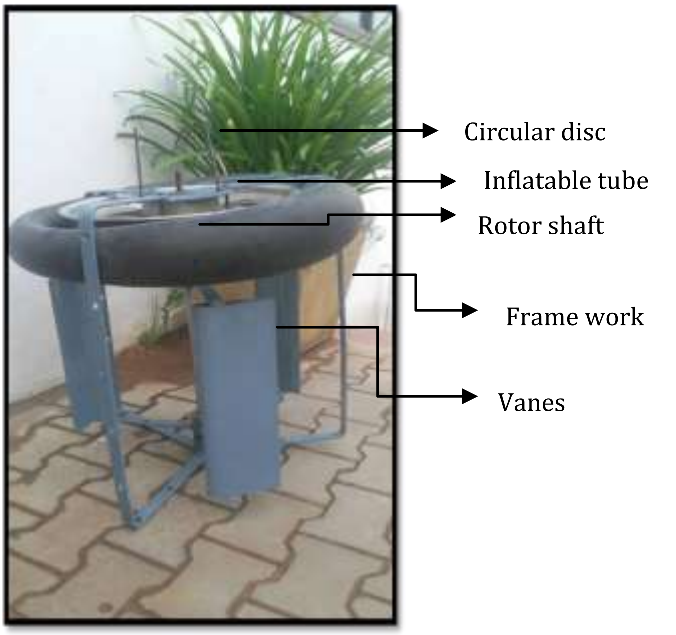

Fig-4: Rotor swimming Turbine

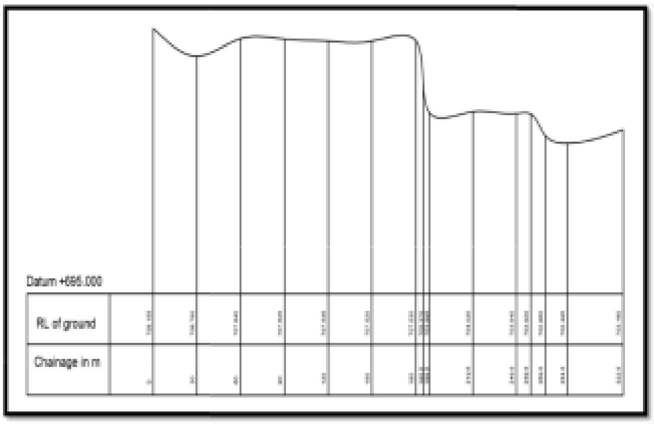

Fig-5: Longitudinal section of Kesare wastewater treatment plant

Table-3: Laboratory test results on wastewater sample

Test	Sample Details		
	Inlet	Aeration	Outlet
pH			
pH paper	8	7	7
pH meter	7.51	7.95	9.43
Acidity			
Total Acidity in mg/l as $CaCO_3$	65	29	0
Mineral Acidity in mg/l as $CaCO_3$	0	0	0
CO_2 Acidity in mg/l as $CaCO_3$	65	29	0
Alkalinity			
Total Alkalinity in mg/L as $CaCO_3$	340	300	336
Phenolphthalein Alkalinity in mg/l as $CaCO_3$	0	0	48
Methyl Orange Alkalinity in mg/l as $CaCO_3$	340	300	288

The turbine was fabricated for two trials. In the first trial the total weight of the turbine was 21kg, due to greater self-weight, the turbine was in the verge of sinking. In order to overcome this, the weight of rim, vane and frame arrangement was reduced. The total weight of the turbine in the second trial was 15.32kg which is 27.04% less than first trail as shown in Table 4. The turbine obtained from trial 2 was tested for two conditions

1. Floating condition
2. Fixed condition

In the floating condition the revolutions were negligible. Whereas in case of fixed condition as the turbine was lifted to certain extent it was observed that there was average of 6 revolutions per minute in the vertical shaft condition and13 revolutions per minute for horizontal shaft. In both the conditions rotation was intermittent.

Table-4: Weight Details

Component	Weight(kg)	
	Trial 1	**Trial 2**
Motor	3.57	3.57
Plate	0.96	0.96
Rim	4.77	1.95
Vane and frame arrangement	11.7	8.84

Table-5: Characteristics of turbine for Horizontal shaft

Horizontal shaft				
Velocity (V_o) in m/s	Speed (N) in rpm	Input power (P_{in})in W	Output power (P_{out})in W	Efficiency (ŋ) in %
2.5	13	2789.06	232.02	8.32
2.5	12	2789.06	214.25	7.68
2.5	12	2789.06	214.25	7.68
2.5	11	2789.06	196.47	7.04
2.5	12	2789.06	214.25	7.68
2.5	13	2789.06	232.02	8.32
2.5	13	2789.06	232.02	8.32
2.5	12	2789.06	214.25	7.68
2.5	12	2789.06	214.25	7.68
2.5	12	2789.06	214.25	7.68

Table-6: Characteristics of turbine for vertical shaft

Vertical shaft				
Velocity (V_o) in m/s	**Speed (N) in rpm**	**Input power in W**	**Output power in W**	**Efficiency (ŋ) in %**
1.6	0	731.14	0.32	0.04
2.1	6	1653.09	0.54	0.03
2.1	4	1653.09	0.54	0.03
2.5	5	2789.06	0.77	0.03
2.5	5	2789.06	0.77	0.03
2.5	6	2789.06	0.77	0.03
2.5	5	2789.06	0.77	0.03
2.5	5	2789.06	0.77	0.03
2.5	6	2789.06	0.77	0.03
2.5	6	2789.06	0.77	0.03

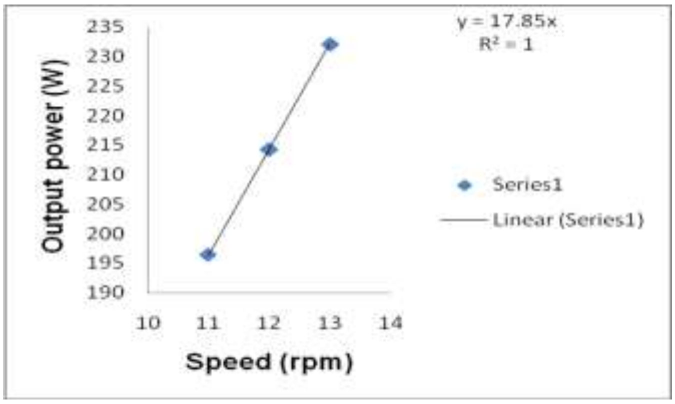

Fig-6: Output power V/S Speed for Horizontal shaft

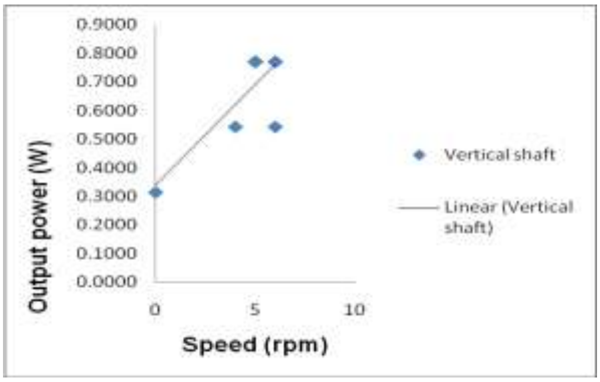

Fig-7: Output power V/S Speed for vertical shaft

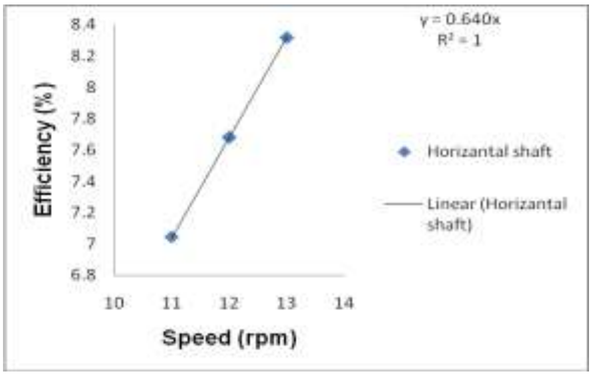

Fig-8: Efficiency V/S Speed for horizontal shaft

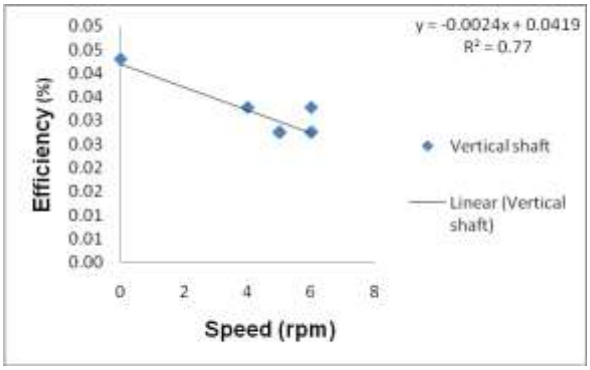

Fig-9: Efficiency V/S Speed for vertical shaft

The graph plotted for speed v/s output power for horizontal shaft and vertical shaft is shown in figure 6 & 7. This shows that, as speed increases the output power also increases for vertical and horizontal shaft method. The horizontal and vertical shaft, characteristics of turbine is shown in Table 5 and Table 6. In this table for the velocity and speed of the turbine the input and output power (in watts) and Efficiency of the turbine is measured. The graph is also plotted for efficiency v/s speed for horizontal and vertical shaft shown in Figure 8 & 9. If the speed increases the efficiency is also increases. Efficiency is expressed in percentage and speed is in Rpm.

3. CONCLUSIONS

Based on the literature citation, experiments conducted and results obtained, the following conclusions can be drawn

1. The horizontal shaft rotor turbine is feasible in power generation when placed 1m from the surface aerator

2. The velocity of 2.5m/s near surface aerators discovered that aerator lagoons are suitable location for turbine

3. The samples tested in laboratory was alkaline in nature which leads to scale formation hence periodic maintenance and proper material selection are necessary

4. The reduction in weight by 27.04% and aspect ratio by 38% of turbine led to floating of turbine and increase in revolutions per minute

5. The rotor swimming turbine is capable of producing 232W in horizontal shaft condition and 0.77W in vertical shaft condition

6. Increase in revolutions can generate more power which can be achieved by modification in the turbine

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