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Assessment of Electricity Generation Potential Energy Through Overhead Tank Using Pico-Hydro Turbine

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Abstract: *This study explores the global demand for green energy production and emphasizes the significance of implementing sustainable practices in buildings. The researchers propose and investigate a concept for utilizing the power potential of high head water in a building's pipelines. By employing a micro hydro turbine, the kinetic energy contained in the flowing water can be efficiently converted into electrical energy. The primary objective of this research is to determine the feasibility of generating cost-effective power using the proposed turbine. The experimental setup consists of a 135mm diameter micro turbine connected to a 12-V DC generator, with the obtained results further validated through simulation. The study employs theoretical calculations based on fundamental fluid mechanics equations. The findings reveal that the power generated increases progressively as the head, or vertical drop, of the water increases. Specifically, the power generated rises from 19.66 W at a head of 3m to approximately 49.15 W at a head of 21m.Moreover, the resulting electric energy generated is quantified as 0.472 kWh at 3m and 1.18 kWh at 21m. These outcomes demonstrate a direct correlation between power generation and increasing head. The study concludes that implementing this approach can yield promising results in terms of harnessing green energy in buildings, contributing to a sustainable and environmentally friendly future.*

Keywords: *Turbine, electricity, water and energy generation*

1. INTRODUCTION

Energy is important input in the process of economic, social and industrial development. Hydro power is a renewable source of energy. It is non-polluting and environmentally source of energy. Overhead tanks on buildings store large quantity of water. Potential energy is converted into kinetic energy. Moving water from water pipe line is fall on turbine, the blades of turbine spins a generator and electricity is produced (Mantravadi, 2015). There is need for developing systems applicable universally for reducing degradation of the environment and benefit the society. A large number of methods for managing and monitoring the environmental sustainability of regional systems have been proposed by the scientific community for more than a decade (Khemani.2013). Adding value, reducing cost, and improving the environment and inter-relation between economic development and environmental protection, leading to a need of an innovative evaluation method is essential (Suresh, 2016). A micro-hydro generation system is to be designed as an alternative energy resource by consuming water from the water tank of residential buildings. This could be a reliable and eco-friendly form of energy (Kurup, 2016). Although hydropower has long been an important resource, only a few recent projects in developed countries such as Canada and US have been reported. This relative neglect may partly reflect the reality that much of the available large- scale hydropower has long-since been exploited, while small-scale projects have had proportionately higher unit costs and have thus often been considered uneconomical. There is increasing energy demand across the world. Due to global warming, there is constraint on the use of conventional sources of energy. Present day demand is to make buildings green (Robinson & Sander ford 2015). The design of pico hydro turbines involves several critical factors, such as turbine type, blade design, and generator selection (Kansakar et al, 2015). Normally, Pico-hydropower system is found at rural or hilly the hydro system applications at hilly area. This system will operate using upper water reservoir which is a few meter high from ground. From the reservoir, water flows downhill through the piping system and it allows the water to accelerate for prime moving system. Thus, the turbine will rotate the alternator to produce electricity. However, this research is conducted to show the potential of consuming water distributed to houses at town area as an alternative of renewable energy source (Smith 2001)

Problems coming from different sources like high cost of fossil fuel, the oil crisis, climate change, technical capacity limits, continuously growing demands and restrictions on the whole sale. These difficulties are continuously growing, which represent an urgent need for using alternative sources to provide possible solutions. One of these alternative sources is to generate electricity as close as possible to consumption demands by using renewable sources that do not cause environmental pollution. Pico-hydro hydroelectricity generation method have great solution because water is necessary for domestic as well as industrial purposes for this reason it is easy to be as an alternative source of electrical energy, since water is readily available. The aim of this study is to assess the electricity generation potential through overhead tank using Pico-hydro turbine. The specific objectives are to.

2. METHODOLOGY

The rotational motion of a turbine in a pipe is driven by the energy of the flowing water. To optimize efficiency, an impulse turbine is recommended due to its minimal pressure drop across the turbine (Nwosu & Madueme, 2013). Specifically, a Pelton turbine can be utilized as it has shown to be highly efficient (Nasir, 2013). The process begins with water entering the casing through an inlet connected to an overhead tank. A nozzle can be employed to increase the velocity of the water. The high-velocity water then strikes the buckets of the turbine before flowing out through an exit pipe that leads to a tap. Despite the extraction of pressure energy by the turbine, this loss is compensated by an increase in the dynamic head caused by gravity. As a result, although energy is extracted from the water, it regains the energy as it continues to flow under the force of gravity. Consequently, there is no impact on the water's output at the tap. The schematic representation of the setup can be observed in Figure 1. Point 1 corresponds to the location on the free water surface of the overhead tank, while Point 2 denotes the position in the pipe just above the turbine. Similarly, point 3 indicates the location in the pipe just below the turbine. The shaft of the turbine is connected to a generator, and the output of the generator is linked to a DC battery.

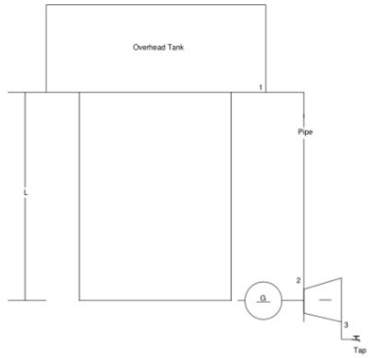

Figure 1: Line diagram of the setup

2.1 THEORETICAL CALCULATIONS

Equation (1) represents the steady flow energy equation in fluid mechanics, which is utilized to determine the velocity at different locations within the pipe. Pipe flow is greatly influenced by friction, so it is taken into consideration. The Darcy-Weisbach equation (equation 2) is employed to calculate the frictional head loss. To determine the friction factor, the Haaland equation (equation 4) is utilized, as suggested by Cengel and Cimbala (2006). In this context, the length of the pipe is assumed to be equivalent to the vertical distance between points 1 and 2. It is further assumed that there are no bends or horizontal sections of the pipe between these two points. Consequently, the steady flow energy equation is applied between points 1 and 2. The values considered for the estimation are shown in Table 1.

$$m\left(\frac{P_1}{\rho}+\frac{v_1^2}{2}+Z_1 g\right)=m\left(\frac{P_2}{\rho}+\frac{v_2^2}{2}+Z_2 g\right) \qquad (1)$$

$$\Delta H=\frac{fLv^2}{2Dg} \qquad (2)$$

$$\mathrm{P}=\mathrm{QgH} \qquad (3)$$

Table 1: Reference parameters

S/N	Parameter	Value	Reference
1	Density of water ρ	1000 kg/m³	(Cengel & Cimbala, 2006)
2	Viscosity of water μ	0.000862 Pa.s	(Cengel & Cimbala, 2006)
3	Diameter of the pipe D	250mm	
4	Pressure	$P_1 = P_2$ Pa	(Bhargav, et al., 2015)
5	Elevation $Z_1 - Z_2$	15 m	
6	Roughness factor ε is	0.000045 m	(Cengel & Cimbala, 2006)
7	Acceleration due to gravity g is	9.81 m/s²	

Equation (3) is obtained through simplification of equation (1).

$$\left(\frac{1}{2}+\frac{fLv^2}{2D}\right)v_2^2-Hg=0 \qquad (4)$$

The theoretical determination of the velocity at point 2 is derived from equation (3). In the context of the pipe flow, it can be observed that the velocity remains nearly constant along the entire length of the pipe. This constancy is attributed to the fact that the cross-sectional area and mass flow rate remain unchanged.

$$\frac{1}{\sqrt{f}} = -1.8 \log\left(\frac{6.9}{Re} + \left(\frac{\epsilon/D}{3.7}\right)^{1.11}\right) \quad (5)$$

The energy generated by the turbine is determined by the alteration in kinetic energy of the water between points 2 and 3. Due to the turbine's small size, the change in potential energy is considered to be insignificant. By applying the energy equation to points 2 and 3, the input power can be expressed as equation (5).

$$\mathrm{W} = \mathrm{m}\left(\frac{v_2^2 - v_3^2}{2}\right) \quad (6)$$

The turbine is specifically designed in a manner that the velocity of the water at point 3 matches the velocity of the water near the tap. This design choice guarantees that there is no impact or disturbance to the water flow at the output of the tap.

2.2 GEOMETRIC MODELLING AND COMPUTATIONAL GRID

Computational fluid dynamics (CFD) is employed to simulate and analyse the flow through the turbine. In this process, the computational domain is constructed using Ansys fluent software. The dimensions of the geometric structure can be observed in Figure 2.

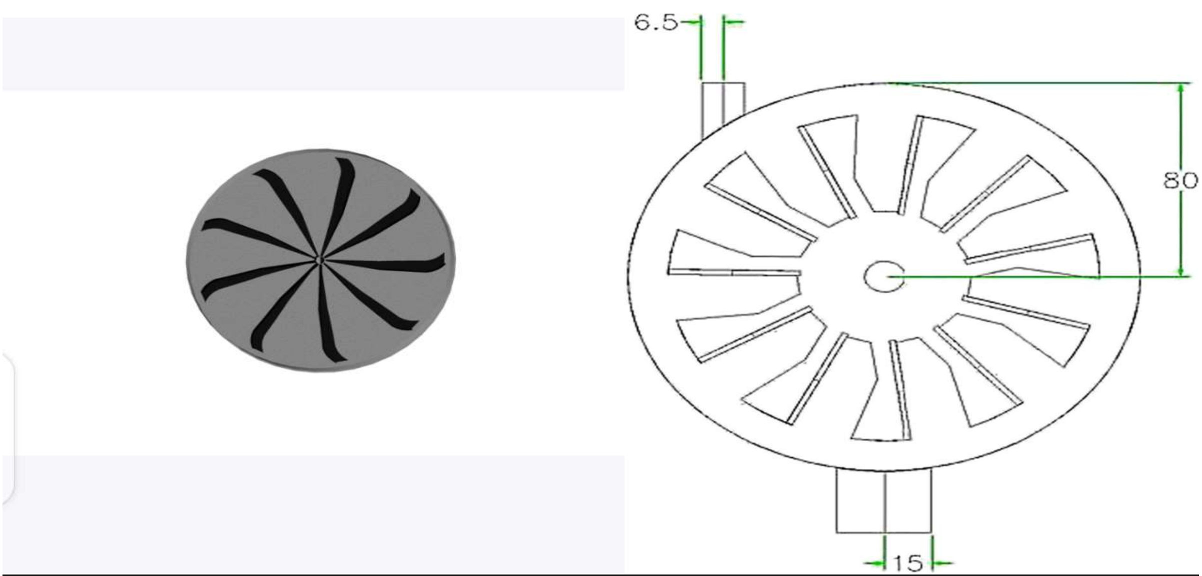

Figure 2: Geometry of the model. All dimensions in millimetres

At face 1, the inlet condition is characterized by an inlet velocity of 2 m/s. The turbulence intensity was set to 5%. The outlet turbine operates at 500 rpm. The turbine casing and rotor are treated as wall boundaries in the simulation. Figure 3 illustrates the solid model of the turbine.

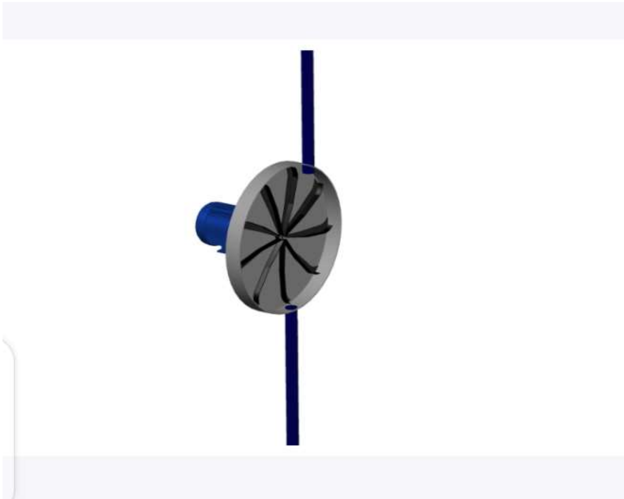

Figure 3: Solid model of the turbine

3. RESULT AND DISCUSSION

The results obtained from the simulation iterations are presented in Table 2. The mass flow rate is determined to be 0.267 kg/s, corresponding to a volume flow rate of 0.000267 m^3/s. The theoretical velocity at point 2 is calculated as 4.361 m/s, while the velocity at point 1 is 0 m/s. The friction factor (f) is found to be 0.02412, resulting in a head loss due to friction (ΔH) of 14.03 m. The Reynolds number (Re) is determined to be 126489.

Table 2: Parameters from simulation

S/N	Parameter	Value
1	mass flow rate m	0.267 kg/s
2	Volume flow rate	0.000267 m^3/s
3	Theoretical velocity at point 2 v_2	4.361 m/s
4	Velocity at point 1 v_1	0 m/s
5	Friction factor f	0.02412
6	Head loss due to friction ΔH	14.03 m
7	Reynolds number Re	126489
8	Turbine power	2.236 W

The moment about the blade wall is found to be 0.18 Nm at 500 rpm. The velocity contour for a cross-sectional plane at the middle is shown in Figure 4. Water enters through the inlet and impinges onto the tip of the blade. This impulsive force rotates the rotor. It is observed that the velocity of water at the tip of the blade is high.

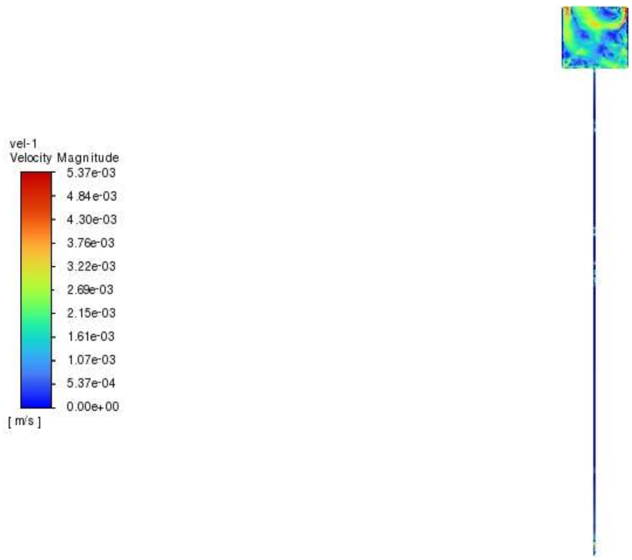

Figure 4: Contours of velocity

Figure presents the power generation and the resulting electric energy generation against the head (m).

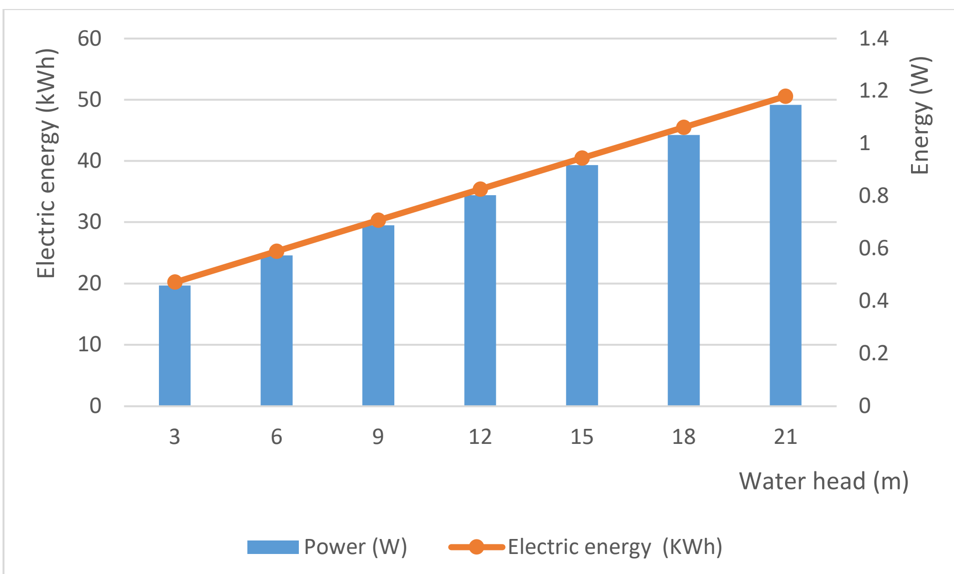

Figure 5: power and electric energy generation for different water head

From Figure 5, it can be observed that the power generated increases from 19.66 W at a head of 3m to about 49.15 W at the head of 21 m. The resulting electric energy generated is 0.472 kWh at 3m and 1.18 kWh at 21m. This implies that the power generation increases with increasing head.

CONCLUSION

Hydroelectric energy has always been an important part of the electricity supply, providing harmless, reliable, and cost-effective electricity. From this result that is been presented, we have seen that the volume flow rate and turbine power are calculated through simulation. By using this technology, the generated energy can be stored in a battery, which can be used whenever required. Hydroelectric energy will continue to play a significant role in the future

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