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Viability of Hydro Kinetic Turbine as an Alternative for Renewable Energy Harvesting in Nigeria

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Abstract: The rationale behind this research is the development of a zero-head floating system using a conventional hydrokinetic water wheel as a model to examine and determine its performance in an open channel condition for energy harvesting in Nigeria. The power is determined by flow of water in the stream which is responsible for rotating the blades. The research entails the water flow driven by a pump at 0.4 m/s and 0.6 m/s water velocities around a pool. The turbine is made to float under this free stream velocity. Feasibility study of its viability in Gari dam in Kano state of Nigeria was carried out and an average flow and discharge were determined during the dry season. Findings of this research were quite impressive and can be used to design a suitable floating zero-head turbine for energy harvesting in Nigerian rural areas where the head is low and energy is required not only for mechanization but also for lighting and irrigation purpose.

Key words: Water wheel, turbine, small hydropower, renewable energy.

1. Introduction

Small-scale hydroelectric power generation is attracting significant attention as a means of utilizing natural energy as a result of problems facing the environment and energy resources [1]. Hydrokinetic turbines, also regarded as free-flow turbines, can generate electricity from the kinetic energy of flowing water, alternately than the potential energy from the water fall head. The main advantage of these types of turbine is, it does not require a civil structured dam, and it provides a relatively convincing power output [2]. Another merit of a micro zero head turbine is little resistance to the onward force of a tide and it also allows marine fauna to harmlessly escape through the rotor blade. Research in this field regarding the impact of design parameters in a low head axial flow turbines like blade height, blade profiles, and number of blades for micro-hydro application continues to be deficient, although there is a need and potential for such type of turbines applications [3].

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Hydropower offers a merit over fossil fuels because it uses water as a renewable source of energy. Water is a clean source of energy and does not release any pollution into the air. Hydrokinetic technology has the potential to generate a great amount of electricity for us with a minimum impact on the environment; hydrokinetic power resource evaluation has been done across the globe [4].

On the other hand, water wheels have been described to be efficient energy converters for small hydropower with head differences h of more than 1 m. Efforts have also been expanded in the search for energy converters for very low head differences (h < 0.8 m) and for the harnessing of fast flowing streams, so far without convincing results. Historically, water wheels were employed to utilize the bracket. Stream wheels already mentioned by the Roman Architect Vitruvius convert the kinetic energy of flowing water into mechanical energy. From the 18th century onwards, stream wheels were frequently used in order to generate mechanical energy. They were considered cost effective since little civil work was required for their installation. It was later realized that the power output from stream wheels in slow flowing situations was minimal; fast flowing streams were however the exception [5]. But the demerit of vertical water wheel was that there was too much influence of the downstream water level which made it impossible to use high chutes as such there was room for more innovation on in this regard [6].

In Nigeria the hydropower potential is estimated to be about 14,750 MW. Unfortunately, only 14 percent of this potential has been harnessed [5]. Considering the availability of small hydropower sources in different parts of the country, the small hydropower potentials in Nigeria is very huge. United nations international development organisation (UNIDO) regional centre on small hydropower (SHP) reported that the gross SHP potential is 720 MW, the technically feasible potential is 606 MW and the economically feasible potentail is 498.4 MW [3].

2. Feasibility Study

With a storage capacity of over 3 million cubic meters, Gari dam (Fig. 1) is located in Kano state of Nigeria. It has a high volume, constant discharge for irrigation and supply to neighboring state. The nearby villages to the dam have no power, making them ideal consumers. The high volume of discharge can also supply enough power to run the dam's water treatment plant. The remote location of the dam will however make the implementation of SHP more tasking. The availability of small rivers in Nigeria rural areas could be developed into SHP's. Through this, we can develop these areas into urban centers with various socioeconomic activities and the rural dwellers need can be met in sustainable way [9].

3. Experiment

3.1 Feasibility Study Technique

In the feasibility study, a downstream flow of the dam discharge channel was targeted. Velocity profile was established using the velocity area method. In this method, a value of the river width was recorded and the depth was measured at five different points to ascertain the profile.

3.2 Data Acquisition

The float was made to flow on water at a distance of 5 m and the timing was recorded. The experiment was repeated five times and the average value of the velocity, cross sectional area and discharge were calculated using a correction factor of 0.85 for sandy soil and the result is shown in Tables 1 and 2.

3.3 Experimental Apparatus

In order to create a continuous flow of water around the system, a water pool of depth 600 mm, width 600 mm and length 1,800 mm shown in Fig. 2 was developed. Flow of water is influenced by a fixed waterproof 300 W dual propeller diving pool scooter pump model BM1207 and diverted by a design curve in the pool. The turbine is located in the convergent throat of the pool at opposite side to the pump allowing it to harness energy from the relatively stable flow of water thereby rotating the turbine using free kinetic energy.

Fig. 1 Gari dam penstock discharge pipe.

Table 1 River profile data.

Distance from left bank (m)	Depth of river (m)
0.2	0.4
0.4	0.42
0.6	0.41
0.8	0.42
1.0	0.41
1.2	0.39

Table 2 Measured parameters.

Item	Value
Velocity (m/s)	0.766
Cross sectional area (m^2)	0.60
Discharge (m^3/s)	0.45

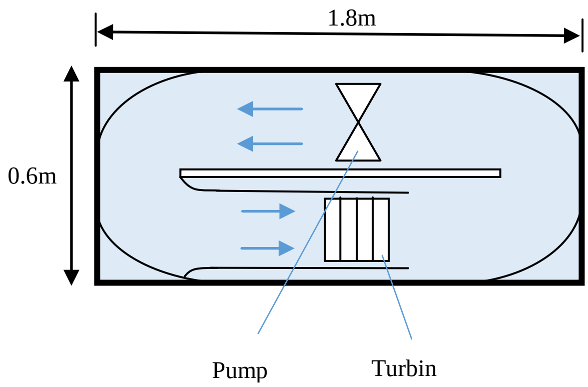

Fig. 2 Experimental model pool.

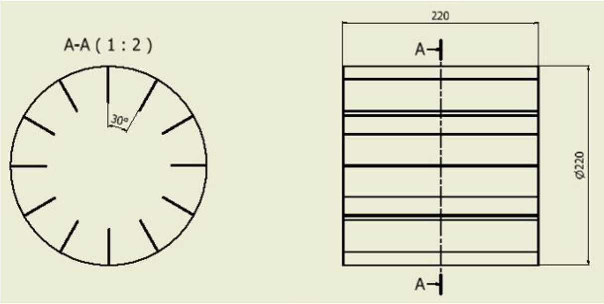

Fig. 3 Turbine layout.

The turbine shown in Fig. 3 has a dimension of 220 mm × 220 mm has 12 number of blades placed at 30° blade angle to each other and was designed using a 1 mm thickness plastic plate. Water level was kept at maximum height of the turbine blade to allow maximum energy to be tapped by the turbine.

3.4 Experimental Data Acquisition

The data targeted for this experiment are the rotational velocity, time and power potential of the system. Rotational velocity and time were determined using a conventional tachometer and stop watch. The experiment was conducted at two flow velocities determined by controlling the pump using a voltage regulator. The pump was regulated at maximum voltage of 12.2 V and minimum of 10.5 V. The velocities of the system that corresponds to the voltages are 0.4 m/s and 0.6 m/s respectively. It should be recalled that at the feasibility study, the maximum velocity obtained is 0.766 m/s which approximates to the value of 0.6 m/s of the experimental model.

3.5 Governing Equations

The value of the output power of the turbine was determined using the principles of applied mechanics. The concept entails adding mass loads to the turbine by transferring it through a rope pulley system until the maximum power was determined at the point of no-rotation of the system turbine. The rotational speed *n* rpm and time (T) at that time were measured. The power is determined using the below expressions.

$$P_t = \frac{1}{2} rmg \times \frac{2\pi n}{60} \times 10^{-3} \quad (1)$$

$$Pin = \tfrac{1}{2} \rho A V^3 \quad (2)$$

The concept was adopted due to the constraints that will not allow us to use electric generator. In this analysis, the experiment was conducted at two speeds of water flow and the efficiency of the turbine was determined. Eq. (1) defines the output power of the rotating turbine (P_t) and Eq. (2) defines the input water flow kinetic energy of the system (Pin). The efficiency of the system is determined using the two equations.

4. Result and Discussions

In the experiment, it was observed that the there is a velocity variation at different voltages which the turbine was made to rotate and the rotational velocity

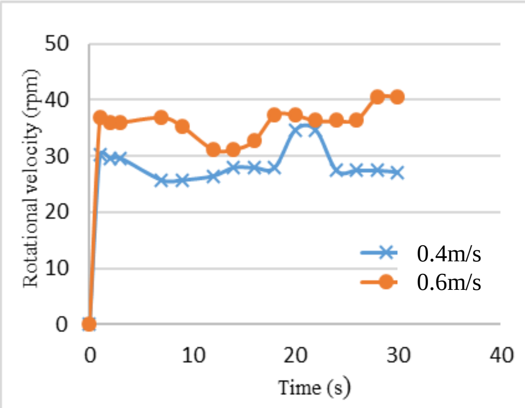

Fig. 4 Turbine performance.

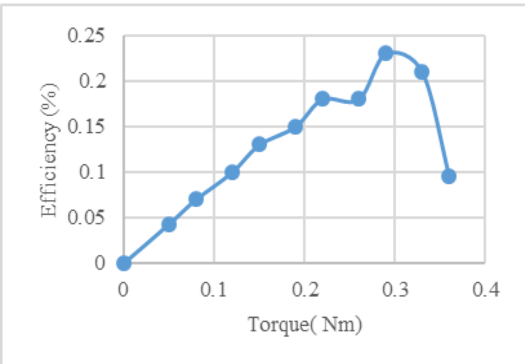

Fig. 5 Efficiency curve.

and time were recorded at different time interval of rotation. The velocity at 12.2 V was measured to be 0.6 m/s showing a higher value than the velocity at 10.5 V of 0.4 m/s.

In Fig. 4, it can be seen that the rotational velocity at 0.6 m/s water velocity is higher having an average rotational velocity of 38 rpm compared to 0.4 m/s flow with an average 28 rpm displaying a higher efficiency tendency at higher flow value. The value of the rotational velocity depends on the flow rate and stability of the water flow. Fig. 5 displays the efficiency curve in relation to the torque at 0.6 m/s applied at different point of application of the load. Maximum efficiency of the system turbine of about 4% is observed showing the percentage conversion efficiency of the kinetic energy of the water by the turbine when the torque is at a value of about 0.3 Nm. The efficiency dropped showing a point of no rotation of the system at about 0.35 Nm due to an overload in the system.

The prototype has been designed and tested for prediction of the performance of the hydrokinetic zero head turbine. The result of the system shows that the turbine displayed a viable behavior for harnessing energy in a zero head condition. Even though the efficiency is maximum at about 24%, utilizing the available harnessed efficiency is important for such type of systems.

Future plan of the research will focus on improving the efficiency and trying a better blade angle for utilizing such potential. Final result of the experiment would be used to design a suitable system for energy harvesting.

5. Conclusions

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