Design And Adaptation Of Cross-Flow Turbine For Small Scale Hydro Electricity Generation

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Abstract: Access to electricity is one of the key recipes for rural development. An estimated number of 1.5billion people in developing countries do not have the needed access to electricity thereby limiting the possibility of economic growth. The design of a cross flow turbine, invented by Nichelle, H and Reichel, R. was adapted to provide a small scale mini-hydro electricity by harnessing energy from running water, generating 3,000 watts of electricity which could be used to power small Communities or Factories. The main characteristics of cross flow turbine is the water jet which passes twice through the rotor blade (arranged at the periphery of the cylindrical rotor) perpendicular to the rotor shaft. Water flows through the blade of the turbine from the periphery towards the center and then after crossing the open space inside the runner, it flows from the inside outwards. Energy conversion takes place twice, first upon the impingement of water on the blade on entry and then when the water strikes the blade upon exist from the runner. The design analysis show that a penstock of cross sectional area of $0.1330m^2$ and a minimum flow rate of $0.746m^3/s$ is required for the design.

Keywords: rural development, electricity access, hydro, turbine, cross flow, water jet.

1. INTRODCUTION

Hydro electricity generator could be referred to as a system that generates electricity from running water. Hydro power systems make use of running water to turn a turbine which generates electricity. The amount of electricity a system generates depends on how efficiently it converts the power of the moving water into electric power.

Hydropower uses water as its source of energy (fuel). This source of energy is not used up in the process because the water cycle being employed here in an endless, constantly recharging system, hence hydropower is considered a renewable energy. Hydropower systems convert potential energy stored in water, held at height to kinetic energy.

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1.1 **Mini Hydro Power Development**

Small hydro power is the solution to providing the needed access to electricity in remote areas relatively far from regional hydro power grid. Research carried out show that an increase focus on decentralization of hydro power energy generation could significantly improve the development prospects of local communities by providing adequate electricity power.

Mini-hydro power provides a reliable, affordable, economically viable, socially acceptable and environmentally friendly energy alternative which could be utilized for rural development.

1.2 **The Cross Flow Turbine**

Cross Flow Turbine is a type of turbine that has a drum-shaped runner consisting of two parallel disc connected near their rims by series of curved blades. Unlike other water turbines, which have axial or radial flows, the cross-flow turbine is characterized by the technique of water passage through the turbine transversely or across the turbine blades. The water is admitted at the turbines edge. After passing the runner, it leaves through the opposite side. Going through the runner twice provides additional efficiency. When the water leaves the runner, it also helps, clear it (the runner) of small debris and pollution. The cross-flow turbine is a low-speed machine that is well suited for locations with a low head but high flow.

2. **DESIGN ANALYSIS**

The suitable site would be one capable of generating a theoretical power of 3000 watts.

Optimizing a reasonable head and flow rate using the formular

$$P = \rho g H Q \qquad (1)$$

Making Q subject of the relation

$$Q = P/\rho G H \qquad (2)$$

Substituting

$$Q = 3000/1000 \times 9.81 \times 0.41$$

$$Q = 0.746 m^3/s.$$

The water jet velocity is given by

$$V = C\sqrt{2gH} \qquad (3)$$

Substituting.

$$V = 0.98\sqrt{2 \times 9.81 \times 0.41} = 5.57 m/s$$

To obtain the cross-sectional area of pipe that allows the flow of water to the turbine (penstock). The formular $A_d = Q/V$ is employed

$$A_d = \frac{Q}{V} \qquad (4)$$

Substituting, $0.746/5.51 = 0.1339 m^2$

The maximum effective speed of the runner is given by the formular

$$N = \frac{39.81\sqrt{H}}{D} \qquad (5)$$

Substituting,

$$N = \frac{39.81\sqrt{0.41}}{0.37} = 68.8 rpm$$

The runner blade spacing is obtained using the formular

$$t = \frac{KD}{\sin\beta} \qquad (6)$$

Where K is a constant and has a value of 0.087 and angle β is 30^o.
Substituting,

$$t = 0.087 \times 0.37/\sin 30$$
$$= 0.06438\text{m}.$$

The radial rim width, which is the difference between the outer and the inner radius of the rim is obtained using the formular

$$a = 0.17D \qquad (7)$$

Substituting,

$$a = 0.17 \times 0.37 = 0.0629\text{m}$$

Top determine the blade radius of curvature the formular $P = 0.163D$ is employed

$$P = 0.163D \qquad (8)$$

Substituting, $P = 0.163 \times 0.37 = 60.31\text{m}$

3. CONCLUSION

Having carefully carried out the steps in the design procedure and fabrication process. The design was tested in order to determine the success of the project, as well as the working efficiency. The revolution per minutes of the output shaft was measured. The correlation that exist between the theoretical expected maximum efficient speed and the actual measured speed was used as a means of evaluating the efficiency of the turbine. The result obtained show that cross-flow turbine is a viable contributor to the energy mix, and also a reasonable and feasible contributor to the energy demand as the developing countries and most appropriate for the off grid electrification system where natural water bodies exist.

APPENDIX

Nomenclature

ρ = Density of water (1,000kg/m^3)
H = Head in meters
N = Angular speed of the runner
Q = Flow rate
P = Theoretical power output
V = Jet water velocity
C = factor of safety = 0.98
β = Blade inlet velocity = 30^o
g = Acceleration due to gravity = 9.81m^2/s
D = Runner diameter = 0.37m

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