RIVER TURBINES

Introduction

The hydro-kinetic turbines are designed to generate electricity solely from the kinetic energy of running water in a river or from tidal currents when used in marine settings. The conventional technique of generating electricity from hydrological energy is done using water from a high position that falls through a head onto a turbine, where water is channelled along canals and pipes in order to make use of its potential energy. This approach is covered in the Practical Action technical brief on micro hydro.

Figure 1: A river current turbine in Peru. Photo: Soluciones Prácticas.

The use of kinetic energy from river currents energy is a less common, alternative approach to hydro power where there is zero head. The energy is converted into electricity or used directly to power a mechanical water pump for irrigation.

Making use of kinetic energy of river currents was a traditional way to mill flour along with wind power but was gradually replaced by fossil fuel systems. There is now renewed interest in river current turbines in a wide range of countries for electricity generation. Practical Action has been involved in promoting small-scale turbines to provide electricity to remote villages in the Amazon and to supply water for irrigation in Sudan.

The power available from the river

Most of the principals of this type of turbine are based upon wind turbines, as they work in a similar way. The power available (P_a) in watts can be worked out using the following formula.

$P_a = ½ \times C_p \times \rho \times A \times v^3$

A = area in metres squared (m^2)
ρ = density of water (1000 kg/m^3)
V = velocity of water (m/s)
C_p = the power coefficient = 16/27 = 0.592 (theoretical maximum power available)

The theoretical maximum power available from the river is expressed by the equation above using a power coefficient of 0.592 or 59% efficiency. But a small-scale river turbine has its own losses which will reduce the power coefficient to around 0.25.

The significant aspect to the equation is that the power increases in a cubed relationship to

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the velocity of the flow of water past the turbine. Therefore it is important to find the best flow to get the best power output.

Hydro-kinetic turbines can be classified into two types. The first is the vertical-axis turbine, whose turning axis is perpendicular to stream flow; secondly, the axial turbine, whose rotational axis follows the direction of flow.

Vertical-axis turbines are preferable in situations where flow direction changes, such as in tidal systems. These turbines are designed so that the direction of rotation remains the same regardless of the direction of flow.

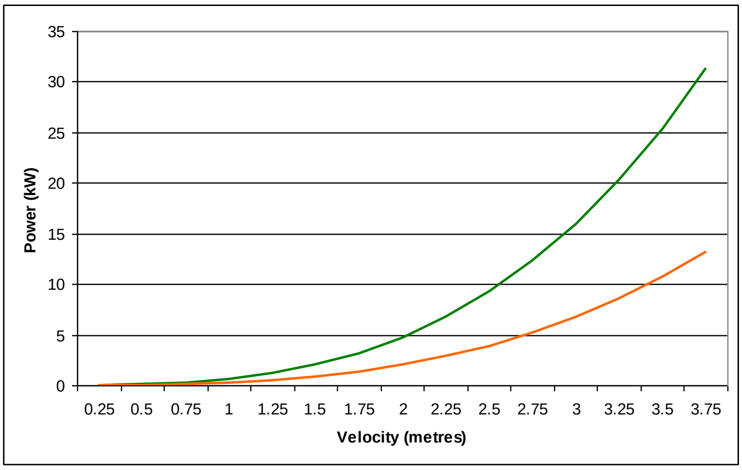

Figure 2: Graph showing the relationship between the speed of the river and the power available. The green line shows the power in the river. The red line shows the power extracted by the turbine.

Putting the theory into practice

For small scale low cost river turbines Practical Action found the second configuration to work due to the simplicity of the design and its greater robustness. It also has the advantage of building on existing knowledge from the small scale wind turbine projects previously undertaken.

The experience from Peru highlighted the importance of siting the turbine. The minimum workable velocity of the river is about 0.8m/s to 1m/s but preferably 1.3 to 1.5 m/s going up to a maximum of 3 m/s for the type of floating turbines Practical Action has been involved in. The engineering would need to be more substantial for higher river speeds.

Larger rivers are better in providing the right conditions for a turbine but flow of a river can vary considerably over the year. In a full river the turbine can be located near to the bank and still work in deep water but during the dry season the water levels can drop and the turbine could potentially hit the bottom.

If the bank has a shallow incline then the edge of the water moves away from its originally position as the water level drops and the turbine needs to be moved further into the middle of the river.

Therefore it is important to find a site that has a site where the water will have a fast flow near to steep banking.

A major hazard for river turbines in large rivers is debris such as logs or trees that have fallen into the river. These can seriously damage the turbine and incur large costs.

Banks can be eroded away or become unstable and in extreme cases the river can change its course. These environmental issues can be more challenging than the technical issues.

The Design

The small-scale design designed by Practical Action focuses on providing battery charging facilities for remote communities. Typically, a small turbine with a capacity of 200w could charge 4 batteries in a day. The machine was manufactured by the local company Tecnologia Energética S.A.C. - Tepersac based in Lima, Peru.

Figure 3: A robust and simple design was developed for remote locations. A simple permanent magnet generator was designed (painted blue). Photo: Soluciones Prácticas.

turbine blades

The design of blades is achieved using concepts used in wind turbine blade with the proviso that in this case, the machine is subjected to much stronger forces with, of course, a denser fluid (water).

In order to calculate the diameter of the rotor, following formula is applied:

$$P = \tfrac{1}{2} \times \rho \times (A) \times v^3 \times C_p \times h$$

$$A = (\pi \times d^2 / 4)$$

$$d = \sqrt{(8 \times P / \pi \times p \times V^3 \times C_p \times h)}$$

d : diameter of turbine rotor (m)
P : power of aero-generator design (Watts)
ρ : density of water (kg/m^3)
V : velocity of river water (m/s)
A : area covered by the turbine (m^2)
C_p : power coefficient (no dimensions)
h : efficiency of the generator

$$\lambda = U/V_D = \pi \times N \times d/60 \times V_D$$
$$N = (60 \times \lambda \times V_D / \pi \times d)$$

N : velocity of turbine rotor (r.p.m)
λ : tip speed ratio
U : tangential velocity at the tip of the blade (m/s)
V_p : design velocity (m/s)

The rotor

- Three fibre-glass blades
- Nominal diameter: 1.75m
- Turning speed: 45 rpm, at 1 m/s to the speed of river flow
- Two stainless steel supporting plates for the bucket mounting

The generator

In order to reduce costs, and to be able to rely on locally-made technology, Practical Action began by working on the development of a permanent magnet generator. The magnets allowed the speed of generation to be reduced, and lowered the cost of the equipment, which itself could be adapted to be a river turbine rotor, and ultimately, tested and built. The main components of the system are: the generation of alternating current which, via a system of rectifying diodes, transforms the voltage to 12V, and 250W of power at 360 rpm.

Transmission shaft
A galvanised steel tube 1.5 inches in diameter, connected directly to the rotor. This tube is layed inside a second, similar tube, 2.5 inches in diameter, which serves as protection and support.

Other component parts

Fan belt
An intermediate component connecting the transmission shaft and the generator, it amplifies velocity.

Control panel
This includes basic measuring instruments and the aforementioned 12V rectifying diodes.

Floats
The floats can be made in a number of ways based on what is most suitable in terms of the materials available. This could be a boat. In Peru balsa wood float(s) were made locally by inhabitants of the village were used as this was the cheapest option.


Figure 4: Setting up the fan belt and permanent magnet generator . Photo: Soluciones Prácticas.

Further reading and bibliography

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Underwater micro hydro 100w generator

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