Water current turbines for Sudan: Using the energy in the Nile

by Barbara Sexon and Peter Garman

A water current turbine developed by ITDG for use in rivers has been tested and is entering its next phase: market surveys and production models.

ON THE BANKS of the Nile in the Northern Region of Sudan, many private farms use a small diesel pump to irrigate their riverside plots. The increasing shortages of fuel and spare parts for these pumps are making farmers look for other ways of watering their crops.

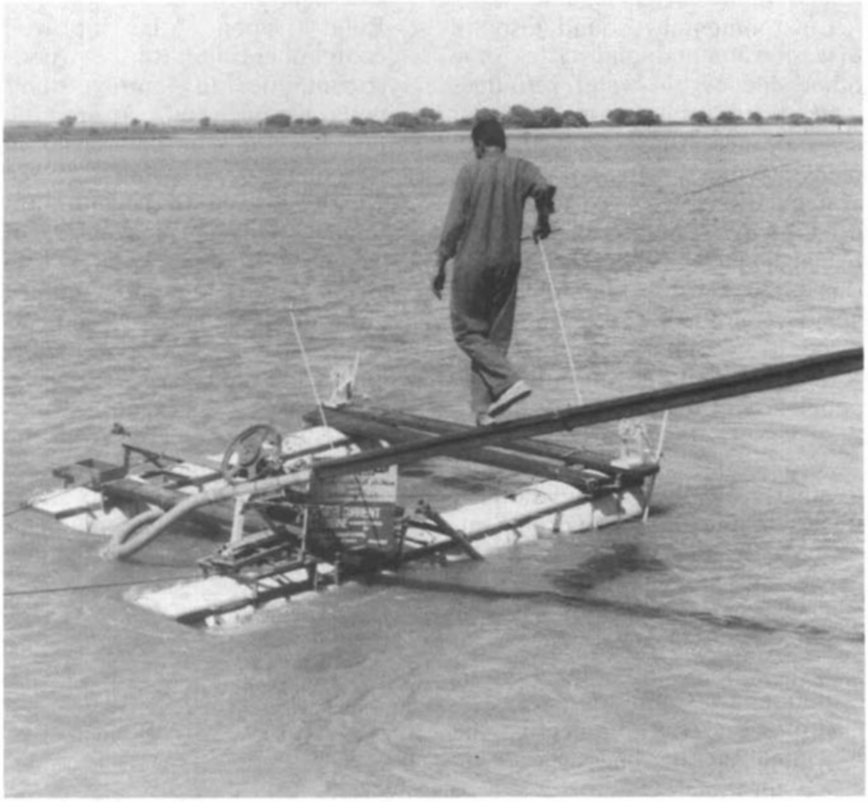
The water current turbine is one alternative which is now being demonstrated in the Region. The turbine makes use of the kinetic energy in the flow of the river to drive a centrifugal pump, delivering water to the bank.

The objectives of the demonstrations are to test the machine over one growing season in the Northern Region; to assess the area that it is capable of irrigating in the conditions prevailing in the Region; and to demonstrate the technology to local farmers and gauge its acceptability to them. This demonstration machine was funded jointly by GTZ and the Energy Research Council of Sudan. It was manufactured at the Mechanical Engineering College, Atbara, and was instigated under part of an ODA-funded link scheme.

Application

A typical application for a river turbine would be on a private farm with about six or seven feddans of land (three hectares) close to the river bank. Such a plot is now normally irrigated using a three-inch Indian Lister-type diesel pump. Crops would include mixed winter vegetables plus fodder crops of *dura*. These are irrigated over the period from late September/ October to April or May.

To give an indication of the level of output from the turbine, the machines currently being demonstrated give an output of 7 litres/s ($25m^3/hr$) to a height of 8.5m, in a river speed of 1.3m/s. The river depth at this site is at least 3m. The turbine is capable of delivering this volume of water for as long as is required, up to 24 hours per day if the farmer is prepared to work that long. In a similar location, a diesel pump of the type widely used in Sudan would deliver about 10 litres/s ($36m^3/hr$).



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The quantity of water delivered by the turbine is dependent on the river's speed and depth, and the height of the bank. As river levels can vary considerably throughout a year, it is necessary to ascertain the minimum likely flow in the river to be able to choose the correct pump and transmission system to suit the particular site. As with another renewable energy technology, microhydro, this technology is site-specific and certain features of the design have to be adjusted to fit each site.

Background

The turbine was first developed in the UK and South Sudan in the late 1970s. The prototype design used a Darrieus vertical-axis rotor as the prime mover. (A detailed account of this machine and its performance is given in 'The development of a turbine for tapping river current energy' by Peter Garman, *Appropriate Technology*, Sept. 1981.)

Using a vertical-axis rotor has an advantage in that the bearings, transmission, and pump can all be positioned above the water-line on a floating pontoon. Only the rotor needs to be in the water. The disadvantage is that the blade and crossarm assembly proved difficult to manufacture and were relatively expensive. A horizontal-axis rotor would have meant placing two bearings and part of the transmission system under the water. The problems of wear because of the ingress of dirt into the bearings made this design impractical, and eventually a compromise was achieved by using an inclined-axis rotor — a horizontal-axis rotor was inclined so that the end of the shaft was above the waterline and only a

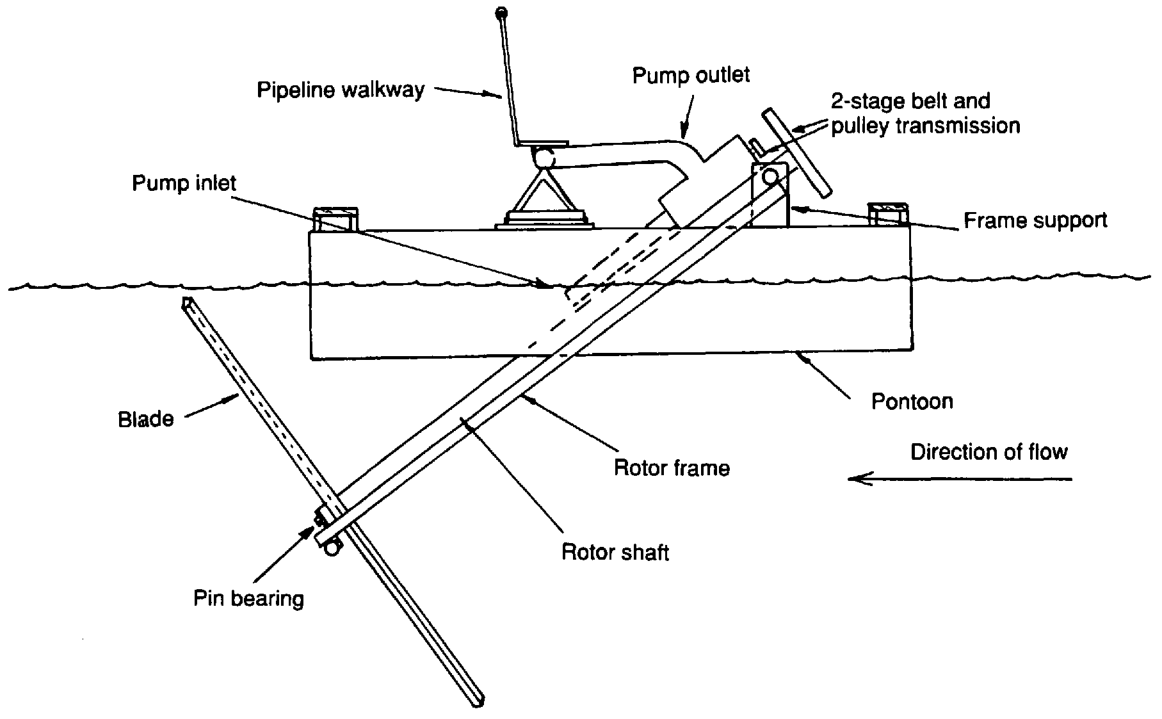

Figure 1. Schematic diagram of water current turbine.

single pin bearing was under the water to support the rotor-end of the shaft. This avoided many of the problems associated with the submerged transmission, at a cost of losing a percentage of the effective area of the turbine. The area 'seen' by the water flow would be an ellipse rather than a circle; for a rotor inclined at 40° to the horizontal, the effective area is approximately 75 per cent of the nominal swept area of the blades. (A detailed discussion of the various different designs is given in *Water current turbines: A fieldworker's guide* by Peter Garman, IT Publications, 1986.)

Development work on the turbine continued in South Sudan until 1983, and then it transferred to Britain. During the 12 years of its development so far, 14 turbines have been built to test a range of design features and between them these machines have achieved 17 000 hours monitored running time.

The two demonstration models currently installed on the Nile in the Northern Region of Sudan incorporate the most successful of these features.

Design details

The turbine is driven by a three-bladed rotor attached to a steel shaft. The blades have an aerofoil section and are constructed of a steel channel core with wooden formers for the leading and trailing edges. They are then covered in aluminium sheet which is wrapped around the wood and steel core and riveted into position.

The rotor shaft is connected to a centrifugal pump via a two-stage Poly-V-belt transmission system. The pump is a standard centrifugal pump (SPP Unistream). The rotor, transmission, and pump assembly is mounted on a frame of water piping. This frame is pivoted to lower the rotor into the water for operation.

The turbine floats in the mainstream of the river on two pontoons made from angle-iron and oil drums. It is attached to the bank via a mooring rope anchored to a post upstream of the turbine. The installation of this post represents the only civil engineering work required at the site. To keep the turbine in the mainstream of the river a rigid pipeline is used. It is constructed of two lengths of water pipe formed into a bowstring truss with support frames and wire rope. This pipeline has three functions:

- By acting as a rigid connection between the turbine and the bank, it keeps the machine in the mainstream and so there is no need for keels.
- The water is delivered to the bank through the water pipe which acts as the main support of the structure.
- A wooden walkway and handrail fixed to the top of the water pipe enables the operators to get to the turbine to start and stop it and to carry out routine maintenance without using a boat.

The rigid pipeline can also be used to control the output from the machine by pushing it further out into the mainstream or bringing it closer to the bank where the flow is likely to be slower. This is done simply by positioning the bank end of the pipeline closer to or further away from the river's edge.

Performance

As stated earlier, the performance of each turbine will depend on certain site-specific details.

- *River speed* The energy available in a flowing river is proportional to the cube of the speed of the water. If the river speed is doubled, the energy available increases eight times.
- *River depth* The depth of the river governs how big a machine can be installed. As the rotor is submerged during operation it is obviously not possible to install a turbine with a diameter greater than the depth of the river. The energy a turbine can absorb from the river is directly proportional to the rotor area.
- *Bank height* For a given power output from the turbine, the volume of water which can be pumped is inversely proportional to the height above the water level to which it can be delivered.

These three factors will govern the mechanical shaft-power that can be obtained, the transmission ratio needed and the pump to be used. The graphs below show how each of these factors affect the possible output from the turbine.

The specification of the turbines used to demonstrate this technology in North Sudan is:

○ *Rotor* 3-blade; diameter 2.9m; inclined shaft at 40° to the horizontal; swept area of 5.06m^2; on load tip speed ratio of 4.

○ *Transmission* Poly-V-belt drive; two-stage; overall ratio of 60.4 to 1.

○ *Pump* S.P.P. Unistream 40/13 centrifugal.

○ *Delivery system* 13m of 65mm bore galvanized steel pipe, 30m of 80mm bore polyethylene pipe, an inlet strainer, a foot valve, a gate valve etc.

Manufacture

One of the advantages of the turbine is that it can be manufactured in a small workshop using mainly materials purchased in the local market. On the current design the transmission belts and pulleys and the pump are the only significant components which have to be specifically imported. The rest of the turbine is fabricated from metal strip, angle, rod, and bar. This is available in the Atbara market, although the design of each machine may have to be adjusted slightly to accommodate changes in material availability. The few more difficult items such as aluminium sheet and pillow block bearings can usually be found in Khartoum. The workshop facilities needed consist of a lathe, pillar drill, welding equipment, and hand tools for metal work and carpentry.

Cost

At present market rates the installed cost of a turbine is approximately three times the cost of a three-inch diesel pump. The main reason for this cost disadvantage is that the diesel pumps are imported through the Agricultural Development Bank and sold to the farmers at a subsidized exchange rate of S£7 to to £1 Sterling. The market rate at the present time is S£20 to £1 Sterling. This is the rate at which all the materials for the turbine must be purchased. Also, diesel fuel is supplied to the farmers at a subsidized price of approximately £9 Sterling per 44 gallon drum.

At current costs the break-even point between the cost of the turbine and diesel pump is about five years. Despite this there has been a lot of interest in the turbine from farmers and potential manufacturers in the Atbara area. If the development banks can be persuaded to import turbine materials at the same favourable rates as the diesel pumps, the costs of the water current turbine would be approximately one-and-a-half times that of the diesel pump, giving a break-even point between one and two years.

Future work

One of the objectives of the current demonstration project was to assess the acceptability of the technology to local farmers. The feedback on the machine has been very positive from all interested parties — farmers, the Sudanese Government, and external organizations working in Sudan. Three more demonstration machines have been ordered by organizations working in different areas of the North for their own assessment purposes.

The next phase of the development is to work towards a production model in 18 months time. Four further turbines will be built to test certain design modifications with a view to increasing turbine performance and reducing the cost per cubic metre of water pumped.

During this test period an extensive programme of site surveys will be undertaken to determine the potential market for the machine within Sudan. Interviews with farmers and development agencies will form part of this market survey.

A means of manufacturing the turbine on a commercial scale will also need to be set up during this next development period. The best method of achieving this will be investigated, either within an existing workshop or by setting up a new manufacturing facility. Any necessary inputs for this will have to be decided on and funds found to provide them.

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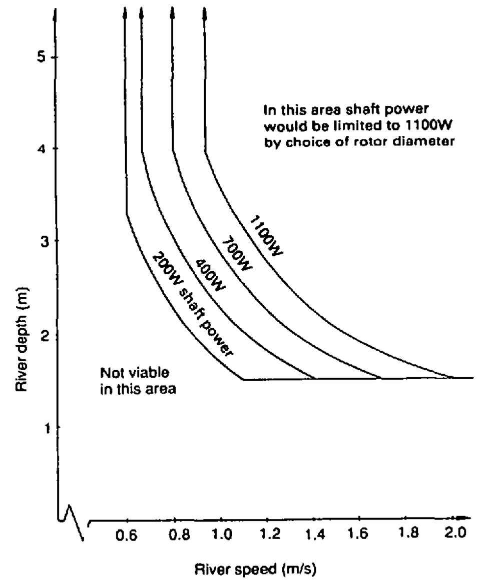

Figure 2. Water current turbine power output for rotor diameters — 1.1m to 3.5m

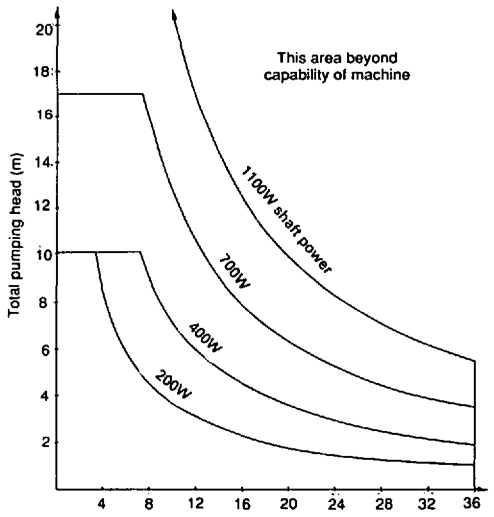

Figure 3. Water delivered vs total pumpimg head