# Windmills under the Waves
# Tidal Current Power

Price 30p

As the moon circles the earth and the earth circles the sun, the gravitational attractions pull the earth's water across oceans where it is funnelled, raised and accelerated around headlands, narrows, and up estuaries such as the Severn. We refer to this movement as tidal, and we know that any moving water contains energy. The interaction of fixed land and moving water causes the tide to move faster and contain more energy at some points. This energy can be calculated. At any moment it is proportional to the quantity moving and the speed squared. There are many 'good' areas around the UK. More than 60,000 megawatts (MW) - the present installed UK generating capacity - flow up and down the Channel daily.

Despite the abundance and, unlike wind and solar, the predictability of this energy engineers felt for a long time that nuclear power was a better option and could meet most needs. In addition, those who were considering ways to extract tidal energy believed the obvious route was by building a barrage. Water would be stored behind the barrage as the tide rose and released through turbines as it fell. In fact a large barrage at La Rance on the French channel coast was built. It has a capacity of 240 MW and been operating successfully for almost 40 years.

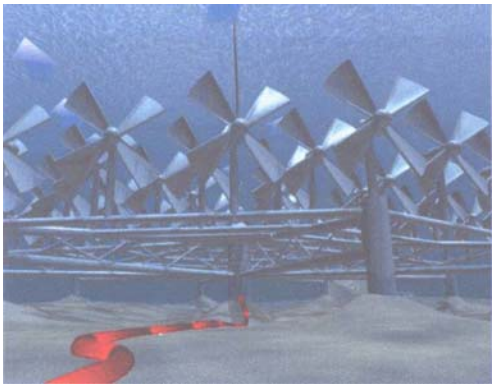

*Fig 1 Artist's impression of a tidal current 'farm'*

The best barrage sites would be those with the greatest tidal range. The Severn Estuary was probably the best and certainly the biggest site in the UK. The installed capacity could be of the order of 9,000 MW and the average power available about 2,000 MW. Unhappily the estimated cost of the Severn Barrage is high, it would take 10 years or so to construct, and would disturb estuarial bird life. The last report remains on the shelf.

Only very recently have engineers seriously begun to consider generating electricity from tidal currents. Turbines can be turned by water just as they are by wind. Moreover water is 800 times as heavy as air so, though the tide will rarely flow as strongly as the wind can blow and the turbine blades cannot be so long, a great deal of electricity could be generated from a small 'windmill' or group of 'windmills', under the water. Even better, they would not be seen. The turbine may be towed from an anchored boat (as was done in a successful trial in Milford Haven) or fixed, as in the current £1.6 M trial in the Severn estuary. This has five, 8 metre diameter water turbines mounted on a steel frame placed on the sea bed (see Fig 1). The most promising device however seems to be the Seaflow, a 300 kW turbine using blades 11 m long in a tidal flow of 2.7 m/sec (Fig 2). The Seaflow is mounted on a column 2 miles offshore from Lynmouth in Devon. Following 2 years operation at end May 2005 funds have been obtained for a 1 MW 'SeaGen' commercial prototype. This will be installed in Strangford Lough, Northern Ireland and should be generating electricity by end 2006. The company is also proposing trials off Vero Beach, Florida. Other research is being carried out at Kvalsund, Norway.

*Fig 2 The Seaflow turbine raised for maintenance*

A different device, called Stingray, was tested in the Yell Sound in the Shetlands. A vane was moved up and down by the tidal flow, so powering hydraulic rams which turned generators. Unhappily costs were high and the Stingray is unlikely to go into production.

John Loveless, of Bristol University, has pursued a subtly different route. His proposal is apparently obvious, once suggested. The problem for tidal systems is that the speed of the current will be


## An ALDES Briefing Note

February 2006

This briefing note arises from a presentation by Dr John Loveless of Bristol University at the Spring Conference 2003. It should be technically accurate but any opinions expressed are those of the editor, Richard Balmer. If you see errors or have comments, please contact him at 79, Links Drive, Solihull, B91 2DJ, or richard_balmer@blueyonder.co.uk

relatively slow most, if not all of the time, and it is technically difficult to extract energy efficiently from slow moving water or, indeed, wind. John's answer is to accelerate the current by constructing not a barrage but a 'fence' or, in technical terms, an Accelerated Tidal Power Barrage (ATPB).

Anyone who has seen water running through what engineers call a 'flume' - a streamlined channel which narrows in the middle - will have noticed that as the water speeds up, the surface level goes down, and then rises again as the channel widens. Some of what is called 'potential' energy (given by the depth of water) is being added to the moving, or 'kinetic', energy. The scientific formula is given by $(h_2 - h_1) = (v_1^2 - v_2^2)/2g$, where $h_1$ and $v_1$, and $h_2$ and $v_2$, are the heights and velocities of the water upstream and in the narrow section, respectively. 'g' is the acceleration due to gravity. In an ATPB the tide would pass between a series of circular 'islands' or piers, and speed up. Very simple Davis turbines, which have vanes on a long vertical axle, could be fitted in the gaps, though more efficient turbines are desirable.

The actual dimensioning of the gaps requires advanced hydraulic engineering design. It is important not to waste energy by creating turbulence. However models of the 'gaps', referred to technically as 'Minimum Energy Loss Transitions' or MELTs, have now been tested at Bristol. If a tide was running at 2 metres/sec a MELT might accelerate the flow 4 times to 8 metres/sec. If an ATPB was constructed across the Severn, where the tidal flow is 200,000 $m^3$/sec, and half the tidal energy was extracted, the power generated would be some 270 MW. This is not the *average* power. That would depend on the range of flow rates from peak to zero over the tidal cycle.

These are illustrative figures only at this stage, but not unrealistic. Blue Energy, a Canadian company and developers of the Davis turbine, are currently negotiating with the Philippine Government for a trial of some kind of 50 MW tidal fence in the Dalupiri Passage which, if successful, could be expanded to 2,200 MW capacity. Others are eyeing the prospects of a fence across the Messina Straits to Sicily, now that the Italian Government has given permission for a privately financed crossing.

One of the great advantages of the ATPB option is its flexibility. Large and small ATPBs are possible. There is no reason why the Thames Barrier for example should not have been designed to generate power, though the flow (about 4000 $m^3$/sec) and hence the power, would be much less than on the Severn.

This is not the end of the story. There is always the problem of cost, but Bristol University have developed innovative solutions to this as well. Because the power of the waves can be so great, most coastal works use massive structures or require protection with heavy boulders or equally heavy precast concrete units such as the 4 arm tetrapods one often sees. These are expensive to produce, move, and place in position. Bristol have developed an 8 sided, *hollow*, precast unit or BRUNO (BRistol UNiversal Octagonal) which is designed to fill naturally (or be filled cheaply) with sand. BRUNOs can simply be placed one on top of another to build walls to protect, or piers to create, the ATPBs. It is believed this light, modular alternative could reduce engineering costs by 80%. Experience in building deep sea oil platforms may also help reduce costs.

Cost could also be reduced if ATPBs doubled as estuarial crossings or coastal defences. Out at sea (and out of sight) there is no reason why wind turbines might not be mounted on top and/or solar panels and wave power devices incorporated. Locking need not be a problem. 4000 tonne craft ply the rivers of Europe without hesitation. Fish movement would be much less affected than with barrages.

In summary then, though so far untested, ATPBs should be relatively simple and quick to construct, with many more potential sites than barrages. They should avoid the amenity problems which affect wind and most other environmental objections. Though they will not give continuous power, output will be predictable. Moreover ATPBs at different locations would 'peak' at different times so increasing their overall usefulness if used conjunctively. It might even be possible to incorporate gates to create partial barrages at the larger sites so that output could be delayed and matched more often to peak demands. There are clearly issues of cost and navigation which have to be resolved, but it is time to begin initial trials.