Notebook

Notebook provides data not easily found elsewhere, background descriptions of important aspects of the energy system and reports on new developments. Contributions are invited.

A Way Ahead for Ocean Wave Energy?

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After the 1973 oil shock, the British government invested substantially in R&D for alternative energy. Quite a large share of this money went into investigating ocean wave power, because the average annual amount of this in British seas is estimated to be as much as 7-10 GW. To investigate about 200 devices, £17 million (Cdn$34 million) was spent, resulting in 600 reports (Price 1990).

An official review of this research work has recently been published (ETSU, 1992). This shows the most promising technique to be the *Shoreline OWC (Oscillating Water Column)*. It is also the only type for which there is actual experience of feeding electricity into a grid.

'Oscillating Water Column' Devices

The operating principle for this type of device is simple, as can be seen from the vertical section in Figure 1. A chamber with an underwater opening to the sea is constructed on a cliff face. As wave energy causes the level of the water inside the chamber to oscillate, air is forced through a turbine to generate electricity.

The first such installation was actually constructed in Norway, but this was destroyed by an

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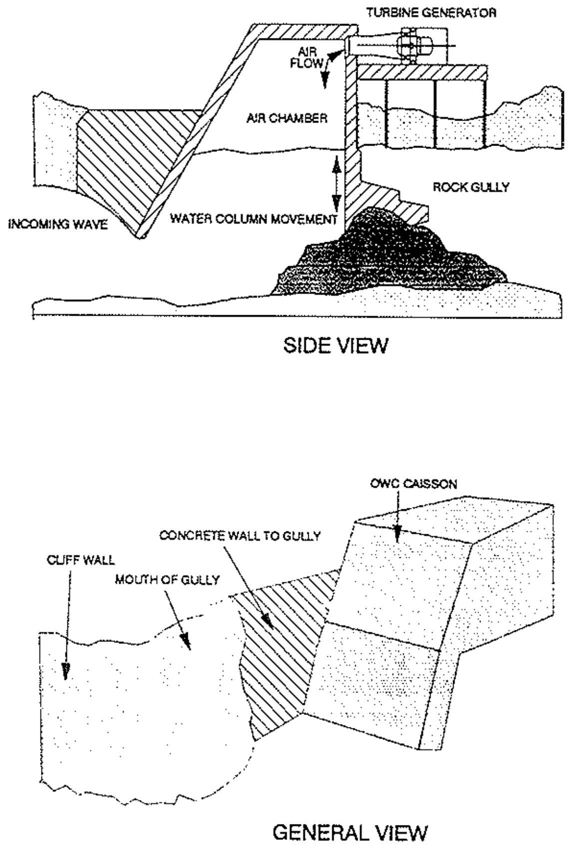

Figure 1: Outline of the Shoreline Natural Gully OWC

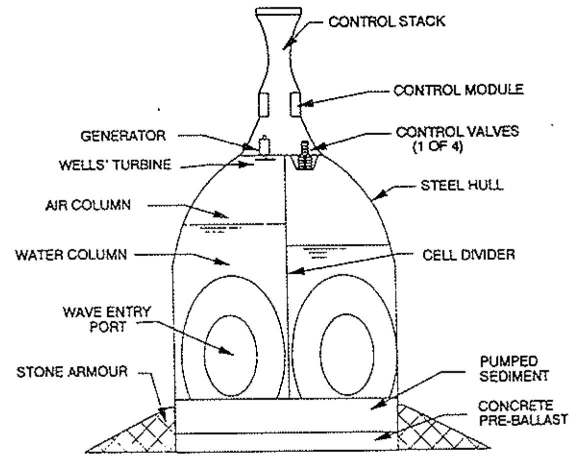

Figure 2: Outline of the Art Osprey

exceptional storm after a year's successful operation. The British version is in Scotland, where it was built in a natural rock fissure to reduce construction costs. This is now recognized as a mistake, as fissures form where the rock is weak, so a considerable amount of unforeseen anchoring was required. It also meant that the water was shallow, resulting in turbulence induced by rocks on the sea bed. This reduces the energy available by half, as compared with having deep water at the shoreline.

A variant of the shoreline OWC which should not suffer from this drawback is the OSPREY (Ocean Swell Powered Renewable Energy) device. This is illustrated in vertical section in Figure 2. It is intended to be located offshore, and the European Union has offered a contribution of £435,000 (Cdn$870,000) towards the cost of a prototype to be built by a consortium of British engineering firms. This would be a two-megawatt unit in the Pentland Firth, near Dounreay, Scotland, and would weigh 7700 tonnes.

Turbine Efficiency

The air turbine used in both Norwegian and British shoreline prototypes was of the Wells type, whose blades turn in the same direction, irrespective of which side is impacted by the air. Wells turbines have been the subject of a good deal of theoretical research (for example, Gato and de O. Falcao, 1988). In practical operation, however, it was found that the airflow pattern did not allow the turbine to be optimized for flow in both directions, thus reducing its overall aerodynamic efficiency to 50%. Using guide-vanes, valving or a different type of turbine, it is thought, could increase efficiency in this area to 70%.

The big question mark about all devices for capturing ocean wave energy is the cost of building them with sufficient strength to withstand exceptional storms. Research in Ireland, for example, has shown that even though the power levels are about 30 kW/m for half the time, they can sometimes exceed 500 kW/m (Lewis, 1990).

As noted earlier, the Norwegian prototype was destroyed in such a storm. The British shoreline OWC prototype was luckier. It was built behind a coffer-dam, which was intended to be removed when construction was completed. In the event, this was not necessary, as another exceptional storm destroyed it, fortunately only when the air chamber's construction had reached a stage where it was strong enough to withstand wave forces of up to 40 tonnes/m^2.

Dealing with Exceptional Storms

Consequently, any future chambers are likely to be constructed *inside* a cliff, the face of which would then be blasted away to give the waves access to the chamber. The builders of the Norwegian OWC plant, Kvaerner Brug, have obtained patents in several countries for this method of construction, which is illustrated in the vertical sectional view of Figure 3. In this, a well is excavated out of the cliff formation and the OWC chamber is constructed inside it. On completion, the remaining external cliff wall is removed.

Using this technique, the British report estimates that electricity could be produced for 6 pence (Cdn$0.12) per kilowatt-hour. It also notes that the Kvaerner Brug system would greatly increase the number of sites where ocean wave energy could be captured, as compared with the first attempt, which sought for and found a natural gully to concentrate the waves. Shoreline ocean wave energy can have little future if it depends only upon such gullies because of their limited incidence. In fact, its best prospects appear to lie in taking the Kvaerner Brug approach further in the direction of cliff *tunnelling*.

Scandinavian Tunnelling Expertise

Because of a combination of geological structure and harsh climate, the Scandinavians lead the world in certain relevant rock engineering technologies, notably the construction of large underground caverns to house sports and music facilities, and for assembly areas, storage, etc. If tunnelling were to be similarly used to form wave/air chambers in cliffs, wave energy ought to be able to be captured along some quite considerable lengths of coastline.

Furthermore, the best locations are where there is considerable water depth, so that the energy of the waves is not attenuated by contact with the sea bed. Such locations are frequently associated with high and steep cliffs, where it is difficult to build structures attached to the cliff face. However, wave/air chambers could be made inside the cliff instead, by tunnelling.

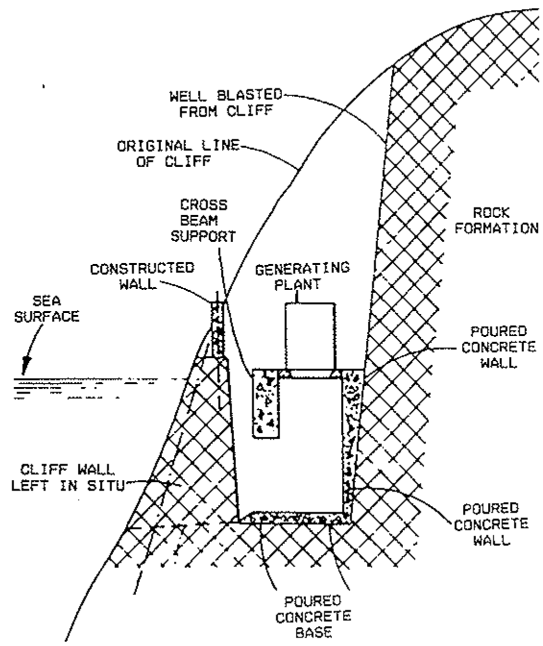

Figure 3: Norwegian OWC Plant

This would enable any conceivable wave force to be dealt with simply by leaving an appropriate thickness of the rock face in place. All work would be carried out inside the cliff, and when this is completed, a section of the rock face would be blasted out into the sea to give the water and waves access to the chamber.

It appears that tunnelling could be significantly less expensive than construction. Scandinavian expertise in excavating very large underground caverns in hard rock could readily be adapted to what is required for capturing ocean wave energy. The 500 cubic meter wave/air chamber of the Scottish plant, for example, cost the equivalent of US$200,000 to construct. At Finnish quoted rates for large cavern projects, the cost of excavating the OWC chamber would have been about one-quarter of this (Saari, 1988, p.67; Winqvist and Mellgren, 1988).

Environmental Advantages

Yet another important advantage of tunnelling over construction is the environmental one. Some coastlines with the best wave energy regimes are in areas of natural beauty which conservationists would be unwilling to see damaged by obtrusive functional structures on the cliff face or top. With tunnelling, nothing whatever would be visible except an occasional small opening like a natural cave, for exhaust air.

This is an important issue. When the British Government privatized electricity, it imposed a "Non-fossil Fuel Obligation" on the new regional companies. This explicitly requires them to buy whatever power is produced by renewable energy at a reasonable price, provided only that it can be fed safely into the National Grid. The incentive of a certain market has stimulated substantial investment in wind-farms. These in turn have split the environmental lobby, because although its members favour alternative energy, they do not like the look or sound of numbers of wind turbines on beautiful hillsides.

The Way Ahead

It looks, therefore, as if progress towards the capture of ocean wave energy in commercial form is shaping up into a contest between cliff tunnelling for the shoreline OWC and the OSPREY offshore OWC device. The arbiter between these is likely to be the costs associated with withstanding exceptional storms.

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