Realities of Wave Technology

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Synopsis

The opportunities offered by wave energy are discussed together with the available resource. The technical challenges are highlighted with particular reference to Wavegen's LIMPET plant on the island of Islay. Areas of application of wave energy technology are discussed.

From where do waves come?

Figure 1

Viewed from Space the earth is a beautiful place with white clouds covering the blue of the sea and the greens and yellow of the land. The whole planet is warmed to a greater or lesser degree by the sun whose nuclear furnace has supplied will continue to supply all the energy ever used by humanity. Through the effects of cloud cover and through the differential heat absorbtion by land and water with differing surface conditions, through the influence of the rotating earth and the effects of day and night different parts of the atmosphere warm to differing degrees creating pressure variations across the globe and the general rotation of the atmosphere. These temperature differences cause density variations which influenced by gravity and the spinning globe cause winds. As the wind drags across the surface of the ocean they drag the water surface with it creating ripples on still water. As the wind continues to blow the ripples become wavelets, the wavelets become waves and if the fetch is long enough, the waves develop into the great ocean swells beloved of surfers. Once formed ocean waves can travel great distances with minimal loss of energy until they break on some distant shore. We thus see that wave energy is simply a derived form of solar power which is constantly renewed by the sun and the engine of the atmosphere.

Wave Energy resource

Just as electrical power is not stored in transmission lines but flows from the generator to the user, so wave energy is not static but flows in the direction of wave propagation. If the energy flowing past a particular point in the ocean or arriving at a shoreline is not captured there then it is lost. Fortunately for the wave energy industry if one wave is lost there will be another one along soon bearing more energy. Because the energy is flowing we can consider the amount of

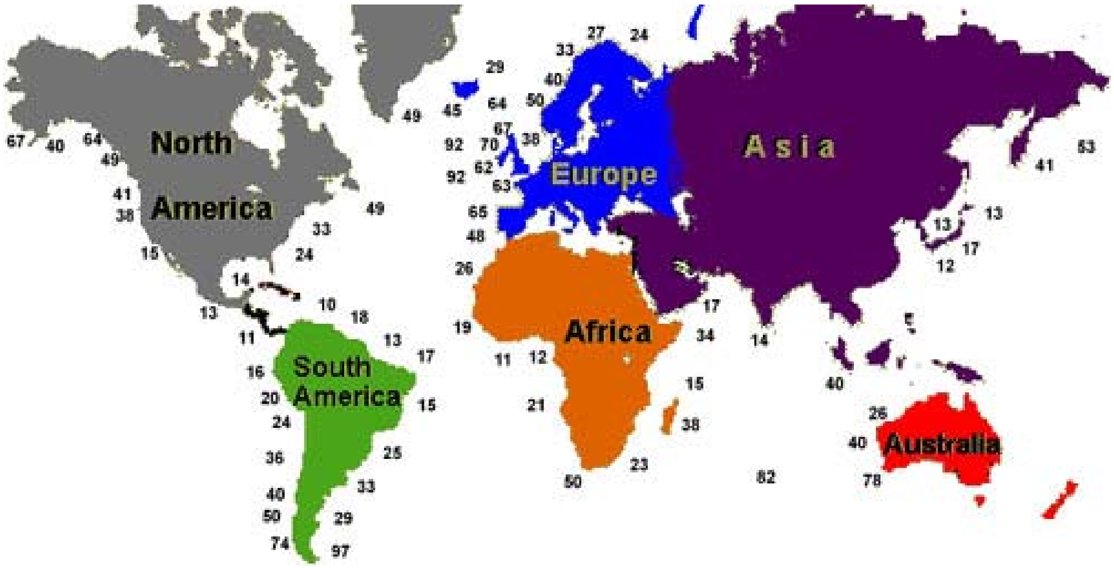

Figure 2

power in kW contained in each linear metre of wave front. Figure 2 shows values of annual average power flux in kW/m at different points across the globe. The quoted values are for deep water sites and hide one of the inescapable realities of wave energy; that a single point value of annual wave power hides the wide variation between the differing power available in different seasons of the year. Off the West coast of Scotland the winter availability may be four times the summer average. In our part of the world this can be considered an advantage because our energy demand in the cold season is so much higher than that in the summer months. This is not necessarily true worldwide. The Atlantic seaboard of the British Isles has one of the best wave energy climates on the planet with 60-70kW/m in deep water off the Western Isles falling to 15-20kW at the shoreline as the effects of bottom friction and wave breaking take their toll. With the land mass of Scotland offering shelter to the south west the available power falls as we move east along the northern coast of Scotland but is still a remarkably attractive 25-50kW/m (dependent on water depth) by the time we reach the waters of Orcadia. The reality is that the power is there, the challenge is to harness it.

The Challenge for Wave Power

For more than two centuries inventors have been filing patents for systems to capture power from the waves and yet we still do not have a wide application of wave energy devices as power generators. So what is the problem? Actually there is no conceptual problem. We can extract power using articulated rafts, nodding ducks, compressible floating bags, tethered buoys, bottom standing oscillating water columns, over-spilling systems, submerged pressure chambers etc etc. Similarly there are no insurmountable technical problems. Whilst there is much engineering difficulty the wave energy community has solutions to just about every aspect of the technology. The reality is that the only long term problem is making the technology work at a cost of power which a consumer is willing to pay. In the long term fossil fuel generation will become more expensive and wave generated power will fall in cost, but until that time the development of wave power is hampered by the need to introduce a fledgling technology into a commercial market dominated by subsidised low cost fossil fuel and nuclear generation. Twenty years ago the wind industry suffered similar problems but largely through the far sighted long term support to manufacturers offered by the Danish government that nation was able to develop an industry which with the premiums offered for green power can now compete on a commercial footing. The wave energy industry is now in a similar stage of development to the wind industry in the 1980's with privately funded prototype devices under development with public support and some public money. There will be failures on the way, that is the nature of technical development, but with sustained public support to create conditions where new energy sources can be introduced to the market there is every expectation that wave power will mature to make a major contribution to our energy needs.

The Technical Challenge

The technical challenge in Wave energy is driven by the commercial challenge. Notwithstanding political considerations the success of wave energy in relation to other energy supply technologies will ultimately be determined by the price at which it can deliver power to the market. The cost of producing wave generated electricity is comprised primarily of the capital expenditure in building and installing the device and connecting to the electricity grid. Capital expenditure typically accounts for more than 90% of the cost of producing wave power. This is in marked contrast to fossil fuel plant where the input fuel is a high proportion of cost. A successful wave energy device will therefore have a minimum capital expenditure and a maximum electrical output. This rather obvious fact creates a dilemma for the designer of wave energy plant. The device structure has to survive the worst that the sea can throw at it; but only just. Looking at it simplistically if we over-design a wave energy machine by a factor of two it will cost twice as much and the price of power will double. We will then have a very reliable wave power device that no-one will want to buy. We thus have to go through a development stage where we build prototype units which, as far as we can tell with the available information, will survive fabled storms and which may not be economic generators but will give us the information on loads and performance to enable the next design to be closer to the limit. At Wavegen we have just gone through this exercise in the construction of our LIMPET device on Islay.

Figure 3

The concrete collector Figure 3, we are assured by the construction engineers, contains a higher density of steel reinforcement that a nuclear bunker. It has also survived the worst storms on Islay in living memory (according to the locals). All the signs are that the extreme service loads estimated prior to the construction may be a factor of 20 higher than those actually occurring so that we now have the opportunity to apply this knowledge to make major reductions in the cost of our next shoreline device.

The long term future of bulk wave energy generation lies in exploiting the offshore resource and as engineers we have to produce optimised designs for:

- The wave energy collector
- Installation
- The power conversion system
- The moorings
- The power transmission system
- Generation controls
- Access and maintenance
- Recovery and decommissioning

As a general rule proponents of wave energy are trying to do everything that engineers have for years been trying to avoid. We are looking to place our structures permanently in areas of high wave activity so that whilst a super tanker might seek shelter we will seek the storm. Whilst a Cruise liner might fit stabilisers for passenger comport we are more often than not relying on a high response amplitude to some form of motion in order to extract power. Whilst ship and offshore jackets are designed to shed wave forces we are, at least in small to moderate waves, trying to interact with them. It is not surprising therefore that in pushing the design envelope of marine structures we are having to develop and extend our analytic tools. These tools then need testing and calibrating against field data; which takes us back to prototype devices and testing.

There is a debate within the wave energy industry as to how to best to develop a wave energy device. There are many schools of thought. Some advocate that everything can be learnt in wave tanks and that there is no need to go to sea until all problems are solved to a high degree of confidence. Others prefer a progressive increase in scale from small tank models, to larger models which can be tested in sheltered waters and thence to the full size. Others believe that the time cost of the progressive approach is unacceptable and that if a device is worthwhile the best way to develop is to build the first unit at the full scale so that real data become immediately available and the route to bulk generation is thereby shortened. There is no doubt that this is could be true but it is equally true that the risk of failure increases with the latter approach. There is also a debate within the industry as to whether research into shoreline generation has any merit or whether all our efforts should be focussed offshore.

Figure 4

With our LIMPET device Figure 4 Wavegen have a vested interest in this debate. We are certainly in agreement that the long term future for wave power lies offshore and are developing a device for offshore application. We also believe that, with our colleagues from the Queens University of Belfast, we have learnt a great deal in the construction and operation of the shoreline plant which will help in the design, construction and operation of the offshore unit. Such areas include:

- OWC performance
- Turbine Technology
- Turbo-generation Control
- Plant safety systems
- Grid Integration
- Data logging and performance monitoring.

We are looking at a class of floating device based on oscillating water column (OWC) technology using a turbine power take off. In this respect we benefit directly from the experience we have gained in operating the Islay plant. In running the unit in all weathers and sea states we have been able to amass operational data which would not have been possible on an dynamic floating structure. The calibration of the turbine for example required a duct flows to be measured at many positions in the duct over a long time period. This was possible on the fixed platform of LIMPET but could not have been done offshore. As such we have knowledge of turbine performance outwith ideal laboratory conditions and are able to more accurately predict and improve performance. Similarly in operating proprietary equipment in the marine environment but on land we have learnt what is likely to work and what is not so that for us LIMPET has proved to be an invaluable stepping stone from the coast line to offshore generation.

Applications of Wave Power

The long term goal for the wave energy industry is to be bulk suppliers of power feeding national grids from offshore wave farms. This will happen in the fullness of time. Bulk electricity generation is not however the only application of wave power. In concert with solar power, wave powered buoys are already used for powering marine buoys. They have also been proposed as pumps for low pressure transmission of water, for producers of high pressure water for desalination and as sea calming devices for coastal protection. Whilst focussing on the offshore potential of wave energy we should not lose sight of the potential of LIMPET type devices. Wavegen are performing feasibility studies for a number of commercial applications of LIMPET derivatives. These range from grid connected generators to OWC systems built as part of coastal protection schemes.

The Realities

The realities of wave energy are thus:

- There is an extremely large supply of power available.
- The technology already exists for the extraction of this power
- The technical challenges are solvable.
- The problems lie in solving the problems at a cost that is acceptable to the market.