Mutriku Wave Power Plant: from the thinking out to the reality

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Abstract

From the very first conception of the wave power plant at Mutriku through to its completion, this article shares the process of maturing and crystallising an entirely new project. Not only was this the first multi-turbine facility to be installed in a breakwater, it was also the world's first commercial project: in other words, a project in which a technology firm sold a power-generating facility to an investor for commercial operation. As well as addressing other issues, the article focuses on the unusual nature of the building process involved in the civil engineering

Keywords: Breakwater, Mutriku, onshore, OWC, wave energy.

1 Introduction

Mutriku was one of the first documented ports in the Basque country. As early as the thirteenth century and even before the town itself was founded, local people were ordered to pay the crown one whale per year in tribute.

Figure 1. Mutriku harbour ortho-photograph

The harbour stands in a small natural bay, (at the top left of the ortho-photograph), sheltered from the north-westerly gales by the Burumendi promontory and bounded to the east by Alkolea Point. The area is regularly lashed by Biscay storms, which over the years have damaged the piers in the harbour and caused major instability and choppy seas in the channel leading into the harbour and the inner docks. This choppiness, combined with the narrowness of the harbour mouth — scarcely twenty metres across — has often made it hazardous or even impossible for boats to enter the harbour. There have been a number of accidents at the entrance, including some fatalities and the reluctance of non-local fleets to enter the harbour has had a negative impact on the town’s fishing industry.

To address this problem, the Basque Government's Directorate of Ports and Maritime Affairs (which forms part of the Department of Transport and Public Works) examined no fewer than 17 different alternatives or lay-outs, including extending the existing breakwater, building an outer breakwater or a submerged breakwater, etc.

The project finally approved and put out to tender received all the necessary administrative authorisations (Favourable Environmental Impact Declaration (published in BOPV of 26 October 2004), favourable Report on Public Maritime-Terrestrial Domain Allocation). The main features of the design were as follows:

A detached breakwater approximately 440 metres in length with a pierhead at either end: Pierhead A, located closest to Burumendi on a sea bed with a depth of around -2.00 m; and Pierhead B at the opposite end at depths of -17.00 m (all heights relative to the MESTLW (Maximum Equinoctial Spring Tide Low Water).

The breakwater is accessed by way of a path around 370 metres long, protected by rockfill.

The breakwater was of sloped type with a concrete haunch and masonry facing running along the entire length. The structure of the breakwater comprised a core of all-one and mantles of rockfill and blocks of natural stone of varying sizes (15t, 25t and 45 t) for the main mantle.

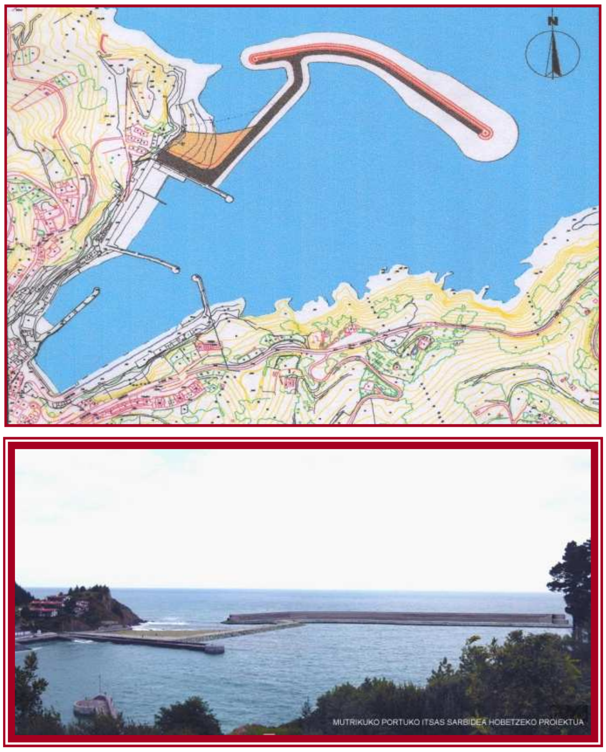

Figure 2. Plan of the arrangement and photomontage.

A plan of this arrangement and a photomontage of how this original design would have eventually looked is shown below.

With the initial project defined, and as part of an overall strategy of developing renewable energy sources, the Basque Government's Department of Transport and Public Works signed a collaboration agreement with the Ente Vasco de la Energía, the Basque energy board to take advantage of construction of this infrastructure to install an ocean energy generation plant.

2 The opportunity of introducing a wave energy plant in the breakwater

With the design completed for a breakwater to resolve problems of access to the harbour at Mutriku, the Basque Government's Department of Transport and Public Works contacted EVE to examine the possibility of taking advantage of the construction work to introduce some form of wave-based power-generating arrangement.

Given that the project was at an advanced state of definition, there were two initial conditions: the proposed solution should not interfere with the breakwater's primary function, to improve sea access to the port, and the design of the breakwater should not suffer too many alterations.

This, then, was the Ente Vasco de la Energía’s starting point: to try to find an arrangement that would be viable both from a technical/energy perspective and in terms of the port infrastructure and the civil engineering, without significantly delaying work on a project that the town of Mutriku had been calling for many years.

2.1. Selecting the technology

Starting with the breakwater designed to solve the problem of access to the harbour at Mutriku, a number of different possibilities were studied for incorporating an infrastructure into the breakwater to harness wave energy.

We analysed the current state of the art of wave energy technologies, to try to find an arrangement that could be incorporated into a breakwater with only a minimum of alterations. It emerged that OWC (Oscillating Water Column) technology could be incorporated into the design of the breakwater while respecting in general terms both the line of the planned breakwater and its functionality.

The OWC devices are simple and non-disruptive. They use the oscillating movement of the waves — though it is important to note that it is not actually the sea water itself that moves the turbines; indeed the turbines never come into contact with the water. As the enclosed figures show, the arrangement consists of a hollow structure, open to the sea below water level with a hole at the top of the chamber.

When the wave comes in, the water enters the chamber, compressing the air inside which is pushed out at high pressure through an opening at the top. This pressurised air turns the turbine, which in turn drives the alternator, generating electricity. When the wave falls, it sucks air through the same opening, again driving the turbine which continues to generate electricity. The fact that it is the air and not the water that moves the turbine considerably extends the service life of the equipment.

Following this initial analysis, we contacted the IST in Lisbon, and Professors A. Falcao and A. Sarmento, who, together with the Spanish engineering firm Boslan, studied the viability of integrating a plant with OWC technology into the breakwater.

The study showed that the project was viable, within the risks inherent to any previously untried installation (i.e. a breakwater containing an important section of "oscillating water columns") using a technology for which there were only a handful of prior experiences, not all of which had been as successful as might have been hoped.

Having selected the technology and analysed the viability, we contacted Voith Hydro Wavegen, the only company in Europe with experience building life-size prototypes connected to the power grid using OWC technology. Voith Hydro Wavegen had worked on both the LIMPET prototype (a facility owned by it on the island of Islay, of the southwest of Scotland) and the prototype on the island of Pico in the Azores. The company is a wholly owned subsidiary of Voith Hydro, which is a Voith and Siemens company.

2.2. Preliminary design and design of the plant

For preliminary design of the plant we needed a detailed study of the sea climate at the site of the breakwater.

In terms of the energy resource, we need to distinguish between three periods: the winter months (November, December, January, February and March), the summer months (May, June, July August and September) and the transitional months (April and October).

At undefined depths, the average value of the resource is 26 kW/m and the average direction of the energy flow is N59W (301º). The annual breakdown is as follows:

- Average energy flow in winter 44 kW/m
- Average energy flow in summer 9 kW/m
- Average energy flow in transitionals 19 kW/m

As it approaches the coast, the energy flow falls in a variable manner depending on the orientation of the coast. Offshore at Mutriku (which is sheltered by Machichaco Head), the values obtained at a point thirty metres deep were as follows:

- Average energy flow in winter 18 kW/m
- Average energy flow in summer 4.8 kW/m
- Average energy flow in transitionals 8.8 kW/m

In this case, it was not possible to choose from amongst several possible locations for the OWC plant, since the position of the plant depends entirely on that of the breakwater into which it is to be installed.

For geometric definition of the plant, a wave propagation study was performed up to the exact location of the Mutriku breakwater at four points along the length of the breakwater (four possible locations and sizes of plant, three on the main section and one on the pierhead) and an evaluation was made not only to determine best wave capture, but also to assess impact on wave reflections and the effects of the reflected waves on navigability for vessels entering and leaving the harbour.

From the study it was deduced that although the location of the plant had no impact on the choppiness of the inner waters, it did have an effect on exterior navigability.

The four proposed options were reduced to two, both in the main section of the breakwater: one location in the area of deeper water, a straight section with a less favourable orientation in terms of the prevailing directions of the waves but a greater depth; and another in an area of less depth (from 4 to 7 metres), in the curved section of the breakwater which was better oriented to the waves.

Once the resource had been measured at each point, the geometry of the chambers was determined: the dimensions of the opening between the chamber and the sea, the straight section of the chamber, the separation between openings, the ratio between the surfaces of the sea opening to and the top opening, the interior height of the chambers, the thickness of the front wall, etc.

Figure 3. Three-dimensional model tests.

With all these data, the two short-listed options were tested on a three-dimensional model to corroborate the findings of the studies and determine the best option.

The location finally chosen (in the shallower are on the curved section of the breakwater) creates a more dispersed area of interference, but the magnitude of interference is less and it is further from the mouth of the port than would be the case if the OWC plant were located near the pierhead (in the deeper, straight section), with interference concentrated more in the area of the shipping channel.

From an energy perspective, there is no great difference between the two locations. The deciding factor was therefore the interference caused in the shipping route (obviously enough, since the whole purpose of the project was to improve access to the harbour!).

Figure 4. Bird´s eye view of the breakwater - Spring-2008

The Mutriku wave energy plant consists of 16 chambers; in each one, the top opening is connected to a turbo-generator set with a rated capacity of 18.5 kW, giving a total capacity of 296 kW.

Wells fixed-pitch turbines have been used, which are more robust and simpler with a symmetrical blade design that means that they always rotate in the same direction, regardless of the direction of the air flow through the turbine, so no device is needed to rectify the air flow.

There are two five-blade rotors that turn in solidarity, separated by the generator, which is air cooled. The turbine set also has an inertia drive so that the output capacity curve is as smooth as possible.

The turbogenerator set, which in Mutriku is positioned vertically (unlike the two aforementioned prototypes) has a butterfly valve at the bottom so that the chamber can be isolated if necessary. This is electrically activated with gravity closing, so that if the connection to the power grid fails, the valve closes automatically.

At the top of each turbogenerator there is a noise attenuator.

Each turbogenerator set has fresh water injectors which regularly clean the blades of any small accumulations of encrusted salt.

The turbine is relatively small — 2.83 metres high by a maximum width of 1.25 metres, with a weight of approximately 1,200 kg — which means that assembly and disassembly operations are not complicated, even when the turbine is removed in a single piece.

In the electrical layout of the plant, the sixteen turbines are separated for control purposes into two groups of eight. The purpose is to help rectify the output capacity curve. Control of each turbine takes into account the pressure reading inside the chamber at any given moment in order to fix the rotation speed of each turbine and optimise the power taken off.

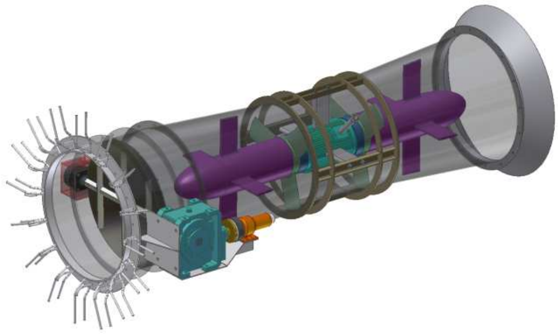

Figure 5. Wells turbine tested at LIMPET.

The generator has a voltage of 450V. Because the turning speed of the turbine, and therefore of the generator, is not fixed but can vary across a wide range, the output signal from the generator is rectified and subsequently converted back to alternating current at 50 Hz in phase with the power grid. It only has to be raised to 13.2 kV to be fed into the local power distribution network.

The cost of the sixteen turbogenerators, control and power conditioning elements, transformer centre and power take-off line, together with the studies and tests for design of the plant, and alterations to the original breakwater design and subsequent testing, comes to €2 million.

The energy output for the plant was estimated by combining model test information from Voith Hydro Wavegen’s test tank with full scale turbine data measured at the LIMPET OWC. To facilitate model testing the annual scatter diagram of sea states at Mutriku were reduced to a set of 14 representative spectra with an associated significance. This was achieved by combining scatter diagram cells with the same period into a single spectrum with the same total power as the constituent spectra. The representative spectra were reproduced in the wave tank at a nominal scale of 40:1 and the pneumatic power capture measured with due compensation being made for air compressibility. The representative spectra and annual average pneumatic power capture for each collector chamber in the MOWC are shown in figure 6.

Spectrum	Hs(m)	Tp(s)	% Significance of Spectrum	Pneumatic Power Capture (kW)	Contribution to AAPP (kW)
1	0.88	5.5	3.23	8.6	0.28
2	1.03	6.5	3.44	13.1	0.45
3	1.04	7.5	5.08	13.2	0.67
4	1.02	8.5	6.11	12.1	0.74
5	1.08	9.5	10.73	12.8	1.38
6	1.19	10.5	9.31	15.0	1.40
7	1.29	11.5	9.52	17.7	1.68
8	1.48	12.5	7.42	21.0	1.56
9	1.81	13.5	2.75	33.1	0.91
10	2.07	14.5	2.96	40.9	1.21
11	2.59	15.5	1.34	63.3	0.85
12	2.88	16.5	0.4	82.4	0.33
13	3.16	11.5	0.27	93.3	0.25
14	3.20	12.5	0.42	96.2	0.40
Total Annual Average Pneumatic Power per capture chamber (kW)					12.12
Number of Capture Chambers					16
Annual Average Pneumatic Power Capture from Plant (kW)					174.5
Annual Average Delivered Electricity (MWh)					600

Figure 6. Representative Spectra and Annual Average Pneumatic Power Capture.

It may be seen that the total significance of the representative spectra is 63%. The remaining waves are too small to generate significant power and are discounted.

Multiplying the AAPP of 12.1kW for each collector chamber by the number of chambers in the scheme and assuming an availability gives an AAPP for the breakwater of 174.5kW. Using the measured efficiency from the pilot plant gives 600MWh/y expected annual average electricity delivered, which will mean avoidance of 600 tonnes of CO2 emissions per year, equivalent to the cleansing effect of 80 hectares of woodland.

The facility has been part-financed by the European Commission's Seventh Framework Programme, under the name of the NEREIDA MOWC project.

The plant was due to be commissioned at the end of March 2009. However, it was not possible to meet this schedule owing to a delay in the licensing process. It is only fair to say, however, that the equipment supplier, VOITH HYDRO, complied strictly with all manufacturing deadlines, (the equipment has been stored in premises in Tolosa since the end of September, 2008, the date stipulated in the contract), and with initiation of the assembly phase.

The wave energy facility is now expected to begin operation during the summer of 2009, once the only outstanding authorisation has been granted. For this purpose VOITH HYDRO has reduced the scheduled assembly time to three months from obtention of the remaining license and start of assembly.

3 Design and construction of the plant infrastructure

The contract for design of the breakwater at Mutriku was awarded in the summer of 2005 and all studies for design of integration of the energy plant into the breakwater were concluded by the spring of 2006. This meant that when work on the breakwater began, a modified design had to be drawn up to integrate the 16 turbines of the OWC plant into the breakwater section.

As explained, the alterations do not affect the alignment of the breakwater or its function as a shelter. What has changed, in broad terms, is the type section of the breakwater along 100 metres of its length (somewhat less than a quarter of the total length) which is now of vertical seawall instead of sloped type, to accommodate the OWC plant.

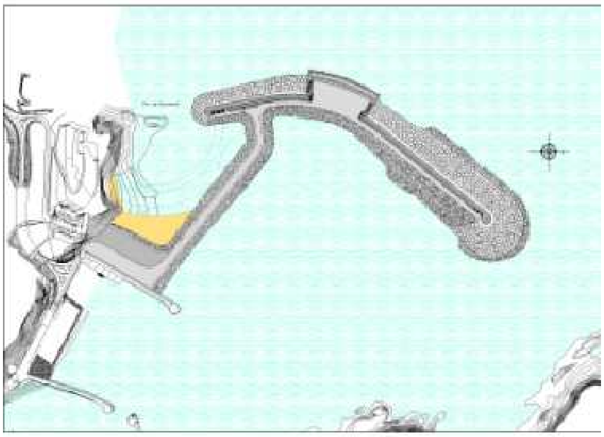

Figure 7. Plan of the arrangement with the OWC plant.

3.1. Description of the plant construction design

The section of vertical breakwater housing the OWC plant has been inserted into 100 metres of the sloped breakwater, in a curved section with a radius on the outer side of 220 m, at a depth of 5 m below MESTLW (Maximum Equinoctial Spring Tide Low Water) with respect to Level 0 at Mutriku port. This means replacing the main mantle of 25-tonne limestone blocks included in the original breakwater design with a vertical parapet that will house the air columns. The vertical section of the plant coincides approximately with the foot of the embankment of the rockfill breakwater, so that insertion of the energy plant does not involve any greater occupation of marine surface. However, the alteration creates a larger platform in the extrados of around 1,600 square metres.

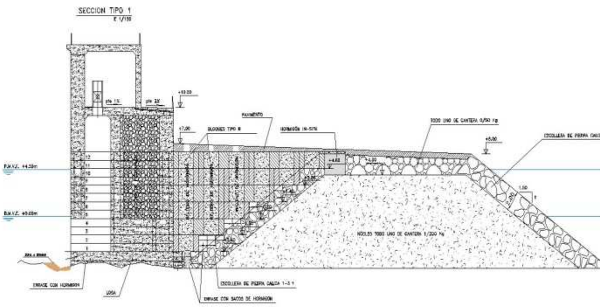

Figure 8. Section at the OWC plant.

The vertical breakwater housing the 16 air columns has been designed with prefabricated parts to facilitate the building process. The power plant has been constructed by positioning these prefabricated parts one on top of another to create the vertical front of the breakwater and the oscillating air columns. The opening that transmits the wave oscillations to the air column is 3.20 metres high and 4.00 metres wide. The lowest point is at -3.40 m, so that the opening is always below sea level.

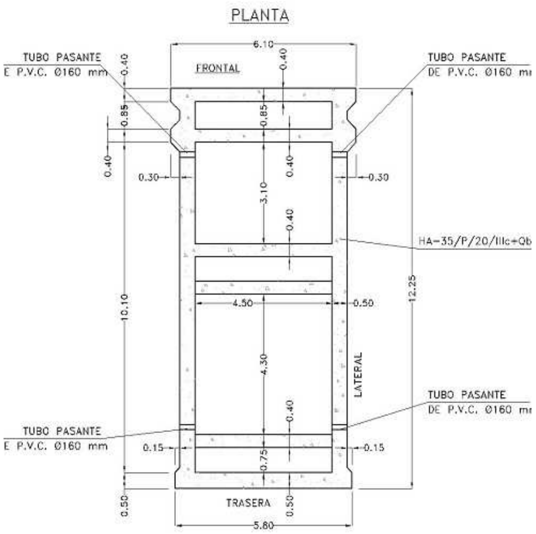

Figure 9. Prefabricated part to build the caissons.

These parts have an external trapezium shape, and are 12.25 m long by a maximum and minimum width of 6.10 m and 5.80 m, respectively, with an edge of 0.80 m. The difference between the larger and smaller bases give the whole the necessary radius of curvature to fit perfectly into the line of the breakwater.

All parts consist of a framework of HA-35 reinforced concrete with walls of 0.40 or 0.50m thick fitted with 2 or 3 lightening cells, plus the cell to house the air column.

The parts vary depending on their vertical position in the breakwater. The first four pieces in each column, from -3.40 to -0.20 m, are open on the sea side, to allow oscillation of the waves to be transmitted to the inner air column. The rest of the parts further up are closed.

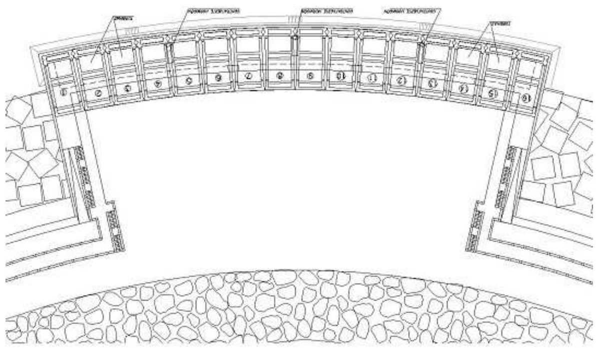

Figure 10. Plan of the OWC plant.

To ensure monolithic performance of the entire structure, the design involves filling some cells with concrete and others with rockfill, except for the 16 chambers that containing the air columns where the oscillation of the water sheet will be transmitted.

The join between the different columns formed by the prefabricated parts is closed off by concreting the gaps, with columns of PVC 400 pipes at the ends to prevent the concrete from coming away.

Above the prefabricated parts, the air column and on the front of the breakwater is continued by means of a superstructure of concrete reinforced in situ, topped by a floor 80 cm thick, on which the turbine gallery is installed. This gallery has a free height of 5.40 metres and a width of 6.10 metres, with buttresses every 25 metres, up to the 16.50-metre mark, like the crown on top of the rest of the breakwater haunch.

The platform created between the extrados of the breakwater/power-plant and the core of the sloped breakwater, is closed off on the sides with prefabricated concrete blocks. These parallelepiped -shaped blocks, 3.00m wide, 6.00 m long and 1.60 m high, are fitted with 2 cells that reduce the weight of the block and ensure that the whole structure is monolithic once they are filled with concrete. To connect the haunch of the sloped breakwater to the gallery of the power plant and completely protect the platform from overflow, the whole assembly is closed with a type section similar to that of the haunch.

The bare walls forming the power plant (except the front facing the sea) and the haunch of the rest of the breakwater, are all covered with 50cm thick limestone masonry, to improve the aesthetic appearance and integrate the power plant into the breakwater and the landscape.

In addition to the masonry, the design includes water, electricity and telecommunications ducts communicating the power plant with the corresponding connection points, connected to the ducts run along the access road leading to the breakwater.

At the same time, in order to integrate the power plant into the pedestrian walkways on the breakwater, the design includes stairs, railings and ramps in the haunch to link the superstructure of the turbine gallery to the rest of the breakwater.

Finally the new platform created in the extrados of the power plant will be paved with 5 cm of mastic of a bitumen mixture of D-12 with 15 cm of base of artificial shingle and 30 cm granular sub base, which is the same section as that used in the breakwater service road.

The budget for procured execution of the modified project comes to €24.5 million, of which €4.4 million corresponds to civil engineering of the power plant and the remaining €20.1 million to the breakwater.

Inclusion of the power plant in the body of the breakwater has increased the construction time by 7 months, giving a total execution period of 32 months.

3.2. Construction of the wave energy power plant

Preliminary work

Work on the wave energy plant started in summer 2006. In order to reach the area of operation from the land, the initial breakwater work (road and embankment) had first to be completed in the extrados of the power plant. Work did not therefore begin until the access road and some 200 of the 440 metres of the line of the breakwater had already been built.

As we have already mentioned, inclusion of the power plant involved a change in the type section of the breakwater, from the initial sloped design to a vertical section. As a result the mantle of 25t blocks was replaced in this area with an arrangement of prefabricated parts forming the vertical front. Nonetheless, in order to carry out the work beside the sea from a safe platform, the 25t blocks were provisionally put in place to protect the surface of the core and filter material that make up the body of the line of the breakwater. The actual work on the OWC plant began from this platform.

Dredging and foundation floor

To lay the foundations of the power plant, a trench had to be dredged to regularise the support base of the infrastructure at a level of -4.50 metres. The material dredged beneath the power plant is of rocky "black flysh" type, associated with the detrital formations of shale and sandstones found all along the coast in this area.

The dredge trench was 14.25 m wide by 102 m long, with a maximum depth of no more than 0.50 m. The trench was dug using a floating pontoon, supported on its four vertices, from which a weight of 3 t was dropped from an 8-metre tripod. The free falling weight broke the rock which was removed with a jawed scoop suspended from a crane on the land.

Figure 11. Undersea foundation works.

Once the dredge trench had been dug, a 20 cm layer of concrete grading was laid, onto which a 90cm reinforced slab was built, which acted as the support base for the prefabricated parts.

The foundation was completed by making 8 anchors with bars of ϕ32 embedded 1.5 metres in rock, and 36 springs introduced 80 cm into the slab which are embedded in the filler concrete of the cells.

Construction and positioning of the prefabricated parts

The prefabricated parts were built on site on a platform constructed at the start of the access road to the breakwater.

The prefabricating and storage area was arranged in such a way that 8 units could be built at a time. The concrete used is of HA-35/P/20/IIIc+Qb type with CEM III/B 32.5R cement. The time taken to remove each piece from the prefabricating area to the storage area was around 3 days. Four through pipes were left in all parts to allow them to be lifted with the crane.

Figure 12. Storage of parts.

Each column consists of 4 open prefabricated parts and 12 closed parts. This means that in total, 256 parts have been built, of which 64 were open and 192 closed.

Each of the parts was placed in its final position from the line of the breakwater, using a motor crane on caterpillar tracks with a lifting capacity of 50 t and a reach of 40 metres. Divers were also employed to correct piece by piece any deviations in the lay-out. The maximum deviations achieved were 3-4 cm, and these differences were graded with concrete at a later phase of the work, when the power plant part had been completed.

Figure 13. Positioning of the parts.

Filling the parts and the extrados

Once the parts had been placed in the final position, the inner cells were pumped with submerged concrete to ensure that the entire structure acted monolithically. From level 0.00 and in order to save on concrete, the 4.30 x 4.50 metres cells were filled with rockfill while the rear cells with a gap width of 0.75 m and the front ones of 0.85 m, continued to be filled with HM-30/P/20/IIIc+Qb submerged concrete and reinforcement framework.

The vertical joins between the different columns were then filled with concrete, using pipes of PVC 400 filled with reinforced concrete acting as piles as a permanent framework.

Figure 14. Vertical section and outline of the breakwater separated

During this phase, the line of the breakwater and the vertical section created with the different pieces was still protected from the sea by a line of 25t blocks. However, once the vertical section of the columns reached the 6.00m level, this protection was removed and the side of the power plant was closed off by fitting the two-cell prefabricated parts and joining the two bodies — the power plant and the core of the line of the breakwater. Rockfill was used as filler in the power plant extrados.

Figure 15. Power plant and breakwater joined

Building the turbine gallery

Construction of the turbine gallery began by covering the columns with prefabricated slabs acting as a permanent framework. An 80 cm slab of reinforced concrete was placed on top, housing the 16 0.75 metre diameter openings, where the turbines will go. Reinforcement of the slab has been calculated taking into consideration the pressures of the air column and the weight of the turbines. In order to facilitate the connections of the installations between the different rooms on the power plant, the design includes through-pipes and ducts linking all the rooms.

Figure 16. Columns before closure

Figure 17. Layout of the permanent framework

The vertical sections of the gallery were made with reinforced concrete of HA-30/P/20/IIIa+Qb type with CEM III/B 32.5R cement poured with a pump using frameworks of conventional phenolic panels. The gallery walls are 1.65 metres wide on the sea side and 0.80 metres wide on the inner side. Inside the gallery containing the 16 turbines consists of 3 buttresses of reinforced concrete, forming 4 rooms.

Figure 18. Covering the columns

Figure 19: Construction of the turbine gallery

Building the impost, apron and railings

Finally, to integrate the power plant into the rest of the haunch of the breakwater the impost, apron and railings were added, which are of a similar type in the different pedestrian areas. The inner face is made of 50-cm thick limestone masonry, like the haunch of the rest of the breakwater. These parts of the work were carried out at the same time as the rest of the sea work and especially when sea conditions prevented other maritime work from being carried out.

Figure 20. External view of the gallery with masonry and impost

Services and Paving

Water, electricity and telecommunications services between the power plant and the municipal connection points were completed after all the ducts were built along the access road. The type trenches were: for electricity, 2 corrugated pipes with of 160 mm diameter; for telecommunications 4 corrugated pipes with of 110 mm diameter; and for supply of drinking water one polyethylene pipe of 90 mm diameter.

Finally the work was capped with the paving of the new 1,600 sq m platform created between the power plant extrados and the line of the breakwater, with the type section described above.

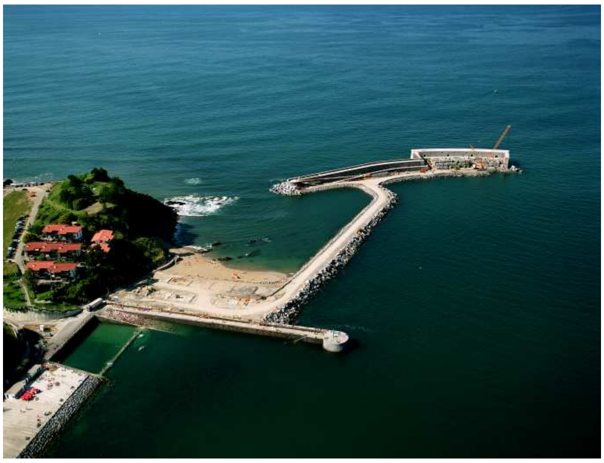

Figure 21. View of the work in June 2008

4 Benefits of the plant

As we have said, in crystallising the original idea for building a wave energy power generation plant, a series of challenges have arisen and had to be addressed.

Naturally, these efforts have been rewarded by the benefits involved in building the plant. These include:

- The plant makes use of a local renewable energy.
- It avoids emissions of 600 tonnes of CO2 per year.
- This is equivalent to the cleansing effect of 80 hectares of woodland.
- It makes additional use of an infrastructure that was going to be built anyway.
- It is an opportunity for development and specialisation in industry and for developing knowledge of marine energy in the Basque Country.
- It will make the town of Mutriku a world reference point in marine energy, helping attract local, regional and even international tourists.
- It will lead to the creation and maintenance of employment, especially in tourism.

5 Frequently asked questions

Since the project was first hatched, we have found ourselves answering four essential questions, namely:

1.- Why Mutriku?

As we have said, the opportunity when a new breakwater was being designed, and the idea of making use of that infrastructure was first posed. The site was not chosen because of the wave resource, but because of the opportunity presented by the construction of the breakwater.

2.- Why OWC?

Because we were using an infrastructure that was going to be built anyway and for which the final design was practically complete, the experts consulted considered that OWC was the option that would require fewest changes to the original breakwater design. At the same time, it is the most tried and tested technology, in a field in which prior experience is in short supply.

3.- What is the cost effectiveness of the plant?

However surprising it might seem, this is one question we cannot answer. We simply don't know.

In the article we give the figures for investment in civil engineering (additional cost resulting from alterations to the breakwater design) and electromechanical equipment and other expenses. Overall investment comes to €6.4 million.

In the article we also state that the estimated annual output is 600,000 kWh.

The problem is that we do not know at what price the electricity will be sold to the power grid.

in Spain, Royal Decree 661/2007 recognises the right to sell the power generated from renewable resources to the grid, and establishes the payment to be received for each type of power generation; this payment is meant to reward the advantages of using renewable energy sources and, at the same time, promote the process of maturing each technology so that it can compete in terms of costs with conventional power generation.

While this arrangement has been internationally lauded for the results obtained in the field of wind and photovoltaic energy (16,000 MW and 3,300 MW of total installed capacity respectively at the end of 2008), the situation in the case of wave power is quite different.

The tariff for wave power is the same as for hydro power. Clearly, this is a bad starting point, since that the same amount is paid to a technology with over 100 years' experience as one that is still at the stage of prototypes and demonstration projects, and has not even reached the commercial phase yet.

Given the clear injustice of the situation, the Royal Decree itself allows the possibility of applying a specific tariff for each facility. However, it does not stipulate the criterion to be used in calculating this new specific tariff. We have therefore gone from a system which is unfair — in that it does reward the efforts being made by the industry to progress — to a system which is unclear, because it is poorly defined and therefore liable to be arbitrary.

Nonetheless, the Ente Vasco de la Energía, as the developer of the project, applied in January 2008 for a special premium for this project. At the time of wring this article, in April 2009, it has yet to receive an answer to this application.

To sum up, in Spain, which has been an international leader in the field of renewable energy, the system for promoting the wave energy industry is unfair (or at the very least insufficient), open to arbitrary interpretation (or at the very least, unclear) and very, very slow... This does not seem to us to be the best way of encouraging the wave energy industry.

4.- Why is EVE promoting this type of project?

For the Basque Energy Board this project is part of a strategic commitment to developing the ocean energy industry in the Basque Country. It is only from this perspective that we can justify a project whose profitability is still unknown even when it is about to be completed.

As an energy agency operating under the Basque Government, EVE can afford to take on this type of project whereas a private investor would have thrown in the towel long ago.

EVE uses the experience gained during development of pioneering projects to bring influence to bear on the government, proposing improvements in the legislative and economic frameworks.

6 Conclusion

We would like to conclude by stressing that the harnessing of marine energy is now a reality; with modest applications, perhaps, but a reality. There are technologies that are now advancing beyond the phase of pilot applications with prototypes, and entering the demonstration phase.

There can be no doubt that all tiers of government need to get more involved, to create a regulatory framework (premiums, processing of applications, etc.) that will really encourage development of the sector.

For Mutriku, the experience means that the town will become an international reference in wave power, and for the Basque Country and Spain it is an opportunity to develop both the industry and the field of knowledge creation (in technology centres, universities, etc.).

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