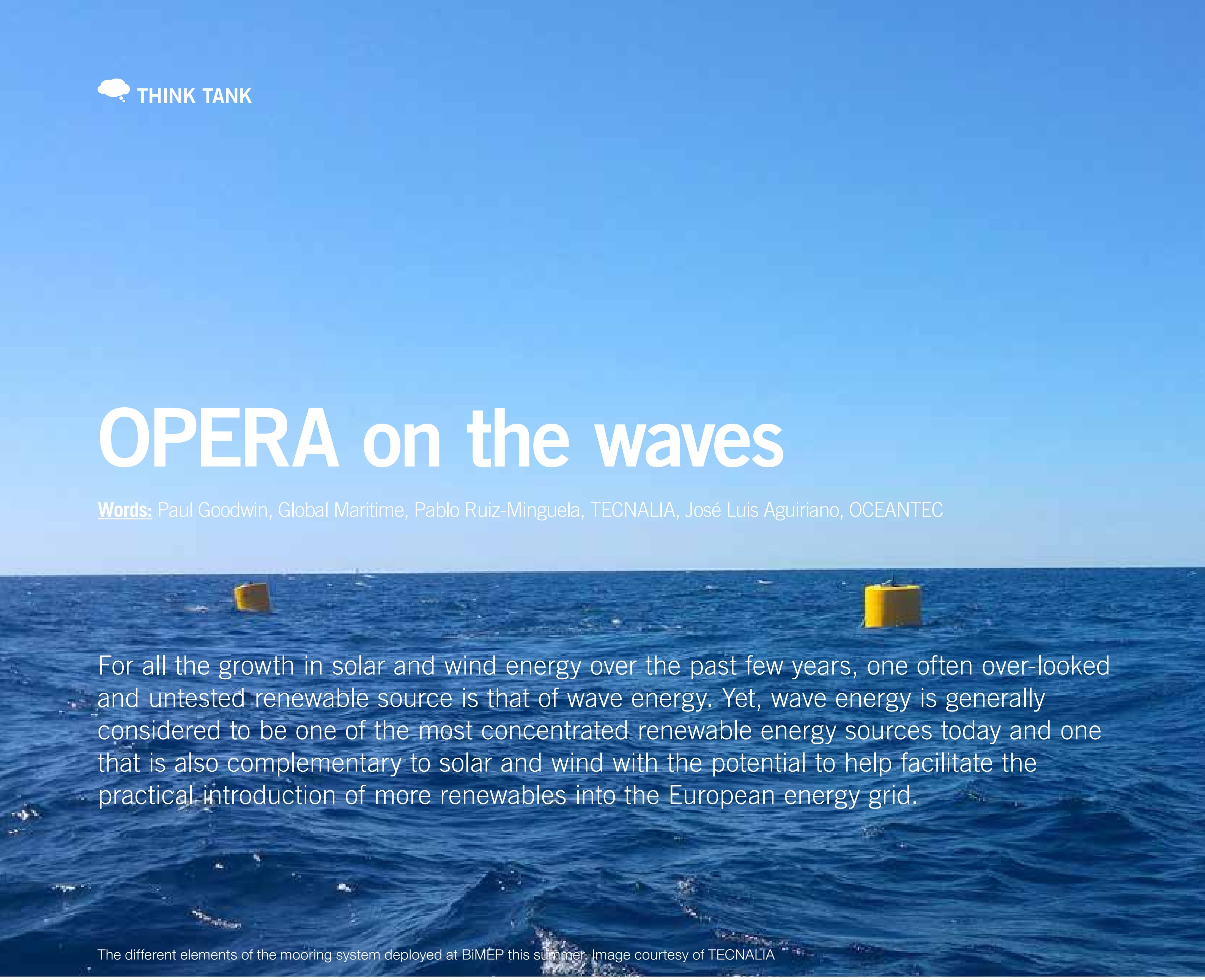
OPERA on the waves

Words: Paul Goodwin, Global Maritime, Pablo Ruiz-Minguela, TECNALIA, José Luis Aguiriano, OCEANTEC

For all the growth in solar and wind energy over the past few years, one often over-looked and untested renewable source is that of wave energy. Yet, wave energy is generally considered to be one of the most concentrated renewable energy sources today and one that is also complementary to solar and wind with the potential to help facilitate the practical introduction of more renewables into the European energy grid.



The different elements of the mooring system deployed at BiMEP this summer. Image courtesy of TECNALIA

Wave energy – opportunities and challenges

The World Energy Council estimates that approximately 2 terawatts (2 million megawatts) - about double current world electricity production - could be produced from the oceans via wave power. The European Union also forecasts that wave energy has the potential to supply some 10% of European electricity needs - about half of today's renewables total.

Yet, despite its attractiveness, potential obstacles remain. Wave energy costs remain high compared to conventional forms of energy and there have been limited open-sea deployments to date. The complexities behind harnessing wave power have also led to a variety of designs and technologies with little consensus as to the optimal approach.

There is therefore an urgent need to share data and experience so as to avoid repeating earlier engineering mistakes and to de-risk wave energy technologies to attract further private sector investment, ensure the transition from R&D to commercial operation, and bring down the greatest barrier to wave energy deployment today – cost. It's against this background that the European Union's OPERA project was born.

The OPERA Project and goals

The OPERA (Open Sea Operating Experience to Reduce Wave Energy Cost) project has been set up to identify and quantify the challenges experienced at-sea in producing wave energy and to prioritize the development and innovations required for solving them. OPERA has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 654444.

The key objectives behind OPERA are to validate and de-risk innovations which can reduce the cost of wave energy by at least 50%; and for the first time provide open access to high-quality open-sea operating data (over two years) to enhance the performance, reliability and survivability of wave energy devices. The ultimate goal will be to reduce time to market of wave energy technologies and ensure a more mature and commercially viable sector.

In order to achieve this, OPERA needed a consortium that would consist of many of the technology leaders and thinkers in wave energy. The members selected were:

TECNALIA (Spain) who are the project coordinators of the consortium; OCEANTEC (Spain); Global Maritime (UK); the Biscay Marine Energy Platform (Spain); Ente Vasco de la Energia-EVE (Spain); IBERDROLA Engineering & Construction (UK); DNV GL (UK); the University of Edinburgh (UK); the University of Exeter (UK); Kymaner (Portugal); Instituto Superior Técnico-IST (Portugal) and University College Cork (Ireland).

The rest of this article will provide a brief overview of the key wave conversion technology platform behind OPERA and examine some of the technologies to be de-risked. In particular, we will focus on the mooring challenges around securing wave energy converter (WEC) technology.

The key technology – oscillating water columns

It was decided to make a floating oscillating water column wave energy converter as the key technology behind the OPERA project with Spanish company OCEANTEC designing and implementing such a device

in a fully consented, grid connected, open-sea testing facility at BiMEP (www.bimep.com). The WEC – a 42-meter-tall spar type converter – will be deployed in October 2016 and is based in the Bay of Biscay up to two nautical miles offshore in 85 meters of water.

Oscillating water columns (OWCs) are simple constructions that act like a piston and cylinder where – as the waves rise within the OWC – the action of a piston is replicated with the column of air ahead of it being driven through a turbine. The OWC moves in both directions (in and out) while the turbine rotates in the same direction.

Such devices offer a highly competitive ratio of power absorption to structural mass which, when coupled with an efficient and effective air turbine power take off (PTO), offer an attractive base device for wave power development.

To date, OWC technology is also the only wave energy extraction technology that has existing commercial applications – being used in navigation buoys and the Mutriku wave power plant in northern Spain. It will be this power plant where the new turbine and control systems will be first de-risked, as described later in this article.

"One of the biggest costs behind wave energy development today is that of mooring."

Using the OWC as the WEC technology platform, OPERA's goal was to de-risk four cost-reducing technologies innovations in the real environment for open-sea wave energy applications. These consisted of shared mooring and later elastomeric tethers, bi-radial turbines, and advanced control strategies. The flexibility of these technologies was also important with – of the four innovations – three were not specific to OWCs and were therefore able to benefit other WEC concepts.

Mooring challenges

One of the biggest costs behind wave energy development today is that of mooring.

A Cable Laying Vessel for the OPERA Project. Image courtesy of TECNALIA.

Mooring typically comprises some 5-10% of total costs for wave energy projects although there are indications this may be an optimistic figure and that in large deployment depths costs can increase substantially.

Part of the reason for this is that little has been done to date to customize mooring arrangements for floating wave energy converters, with a focus instead on oil & gas standards and the mooring of large-scale semi-submersible drilling rigs.

However, experiences in mooring other large-scale ocean structures, such as offshore fish farms, suggest that an integrated mooring system can reduce mooring costs by as much as 50% in WEC arrays – a key objective of OPERA.

How can this be achieved?

While depth, tidal current and tidal range are key influences in the design and cost of mooring systems, so are the mean and extreme loads placed on them at sea. Therefore reducing the loads on the mooring lines can lead to substantially reduced costs.

At the same time, however, the security of such moorings must never be compromised. Several WEC losses in the past have been traced back to mooring and short-cycle fatigue at the connection with the hull.

Another fundamental design question is obtaining the necessary balance between the mooring restoring forces that secure the floating structure, while at the same time ensuring that the energy extraction modes from the wave energy devices are not impeded.

Effective mooring solutions must also be able to withstand a wide variety of conditions – from storm conditions and an ultimate limit state (where the individual mooring lines have adequate strength to withstand the load effects imposed by extreme environmental conditions) to a fatigue limit state as a result of cyclic motions induced by the waves.

It's with these issues in mind that Global Maritime will contribute to OPERA as an industrial partner with hands-on experience in the design, modeling, analysis and simulation of floating structures according to existing offshore standards and rules. Global Maritime also has a significant track record in the delivery of mooring designs to the oil and gas industry.

The WEC is to use a novel shared mooring arrangement that consists of conventional tethers and a design where the mooring is configured for multiple devices, shares lines and consequently reduces the number of anchors. This leads to lower costs. Global Maritime will help ensure that the mooring system is robust and deliver telemetry and tension data, if required.

Global Maritime will also provide assistance on the definition of the underpinning numerical methods to assess mooring performance based on the data collected from sea trial experience and will draw on its extensive experience in marine operations to indicate the duration and limits of operational windows.

In partnership with DNV GL who will lead on developing technology qualification methodologies and will quantify the risk aspects of the components and systems behind the innovations, Global Maritime will contribute to improving the overall design of the project's mooring and maritime operations, thus helping reduce uncertainties, risks and costs.

Elastomeric mooring tethers

As the project continues into phase two in the Summer of 2017, elastomeric mooring tethers, developed by the University of Exeter, will also be tested as a means of reducing peak loads at mooring and hull connections. The University has over

"One of the main challenges to OWCs today is the low efficiency of the air turbines that are often below 50%."

Deployment of the mooring system at BiMEP. Photo Courtesy of Oceantec Energies Marina.

20-years experience in wave analysis, resource modeling, marine hydrodynamics, moorings, testing, reliability engineering, installation, offshore operations and maintenance.

The mooring tether combines the material properties of elastomeric and thermoplastic elements, providing a 'low stiffness' when facing normal operating conditions and a 'high stiffness' in extreme, storm-like conditions.

Laboratory results so far indicate that the elastomeric tethers can reduce loads by as much as 70% (an OPERA objective) with the hope being that elastomeric mooring will improve structural survivability and reduce mooring line strength requirements and costs.

Elastomeric tethers are also expected to greatly enhance survivability with respect to a low-cycle fatigue failure mode for mooring connections.

The de-risking of other technical innovations

Other technologies, in addition to the mooring solutions, that will be tested and de-risked through OPERA include a bi-radial turbine and new adaptive and predictive control algorithms.

One of the main challenges to OWCs today is the low efficiency of the air turbines that are often below 50%. Laboratory results, however, indicate that a novel bi-radial turbine could increase the annual turbine mean efficiency of OWCs by 50%.

As a result, OPERA will focus on advancing bi-radial turbines to a high level of technology readiness during the project, delivering significant amounts of open-sea data.

Another challenge to successful wave energy today is poor energy capture due to the narrow bandwidth of point absorbers – wave energy capture devices. This is why OPERA will focus on new adaptive and predictive control algorithms that - at virtually no additional cost - can greatly increase power production and device reliability through using incoming wave information for increased control.

OPERA will therefore conduct the first at-sea implementation of control algorithms that act throughout the power conversion chain from the hydrodynamics of wave absorption through to turbine aerodynamic and electrical equipment efficiency. The OPERA objective from the de-risking of the technology is a 30% increase in energy production.

Both the turbine and advanced control innovations will be first tested at the Mutriku shoreline wave energy plant and later at BiMEP, an open-sea testing site connected to the grid. BiMEP is a fully consented facility with supporting services – 24/7 surveillance, for example – that contributes to further risk reductions.

A crucial element of the future energy mix

Wave and tidal energy is a tremendously important element of the future energy mix and is why OPERA has such ambitious goals.

From a 50% increase in air turbine energy efficiency to a 30% increase in energy production; the reduction of extreme loads by 70%; and 50% reduction in overall mooring costs in arrays, OPERA's objectives are both bold and potentially groundbreaking.

We look forward to unveiling some of our results over the coming months as we see a growing acceptance and deployment of this vital source of renewable energy. ■

WECs in a shared mooring arrangement. Image courtesy of Oceantec Energias Marinas.

For further information, please visit www.opera-h2020.eu