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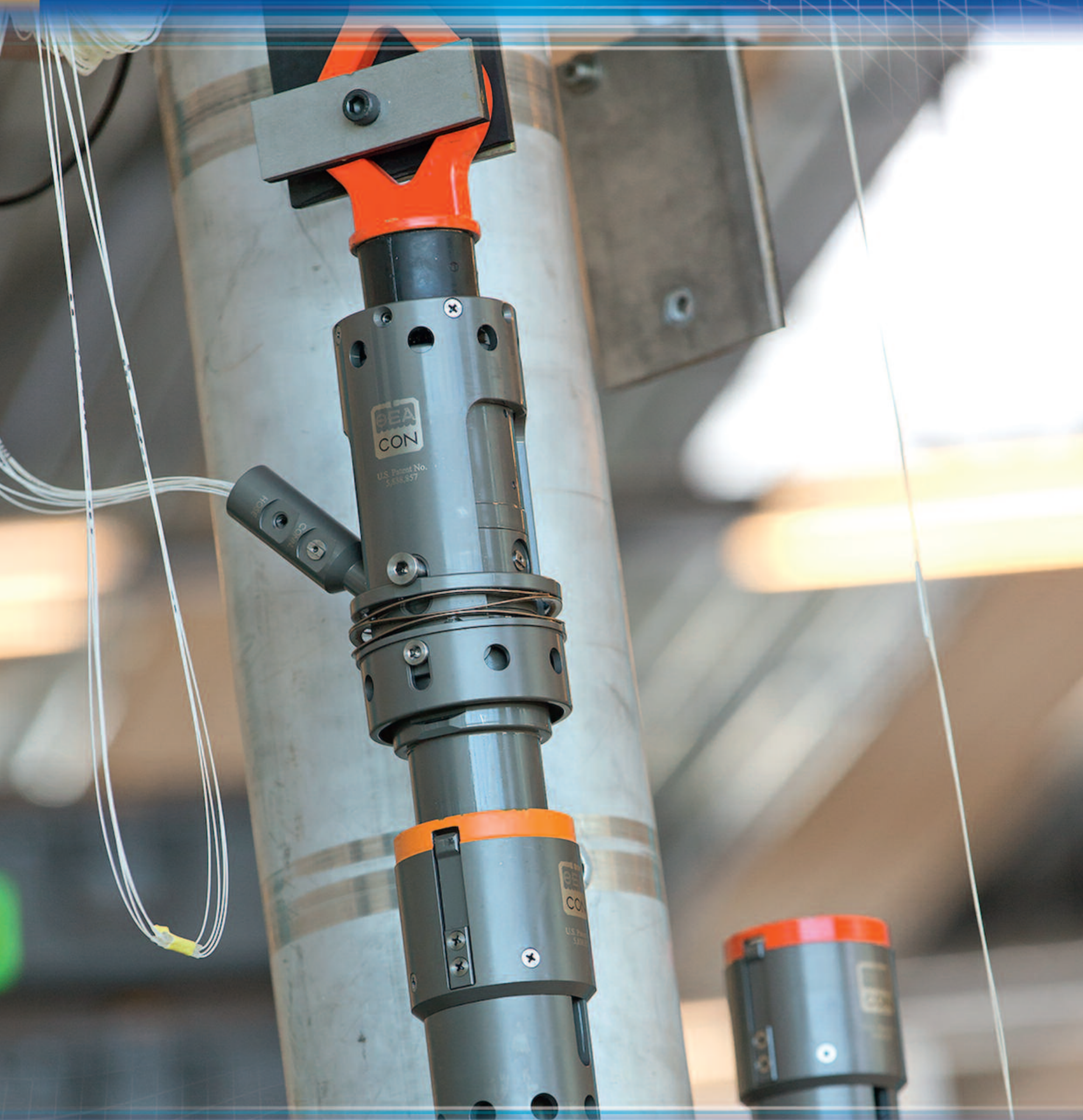
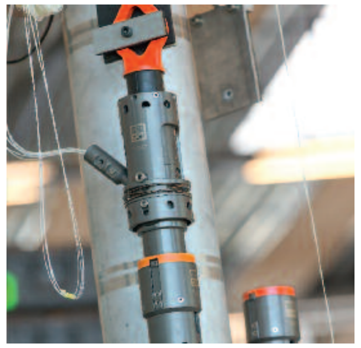


CONNECTORS/CABLES/WINCHES; OFFSHORE RENEWABLES/OFFSHORE TECHNOLOGY



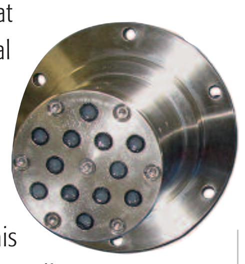
Connections for the marine renewables industry

By David Pye, renewable energy business development manager, SEA CON®, USA, and Michael Mulcahy, president, Michael Mulcahy & Associates, Inc., USA

Electrical and fibre optic connectors for the marine renewable energy market

Alternative marine energy sources have intrigued scientists and engineers for decades. Given that non-renewable energy sources – including oil and gas (O&G) – are finite, the field of marine renewable energy has great appeal. One noteworthy example is Ocean Thermal Energy Conversion (OTEC), which became a national priority for several countries in 1973 when the Arab-Israeli war resulted in the tripling of oil prices. Two other marine renewable energy sources – wave and tidal – have come to the forefront in R&D efforts in the last decade. Development of conceptual wave and tidal electrical power generators is progressing in several countries worldwide, and some of these are nearing the stage where the installation of the first arrays can be considered a possibility.

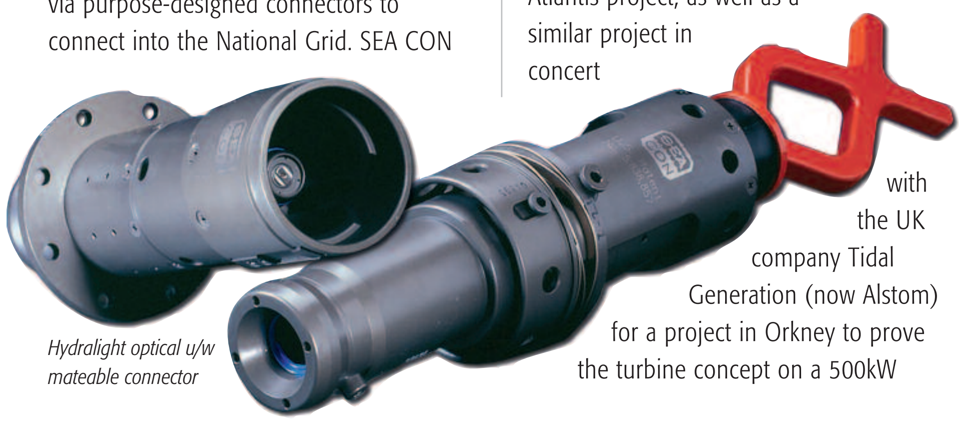
Orkney, a 70-island archipelago off the northern coast of Scotland, is the geographic focus of an international collaboration partially funded by the UK government to transition the concept of generating wave and tidal electrical energy via purpose-designed connectors to connect into the National Grid. SEA CON (europe) Ltd, the Great Yarmouth, UK, regional base of the USA company SEA CON, is providing connector industry expertise to the project to make this well-defined concept a reality.



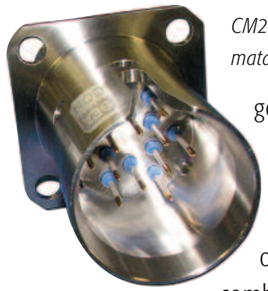
BACKGROUND

In 2003, the European Marine Energy Centre (EMEC) was established in Orkney. The EMEC was originally funded by the Scottish and UK governments, the Orkney Islands Council and other organisations. It claims to be the "first and only centre of its kind in the world to provide developers of both wave and tidal energy converters – technologies that generate electricity by harnessing the power of waves and tidal streams – with purpose-built, accredited open sea testing facilities". The EMEC is now coordinating multi-national R&D efforts in a project seeking to make wave and tidal energy commercially viable.

In 2008, SEA CON began looking into the crucial connector side of the process of bringing marine electrical power ashore and supplied a pressure-balanced, oil-filled (PBOF) Hydralight connector to the Atlantis project, as well as a similar project in concert with the UK company Tidal Generation (now Alstom) for a project in Orkney to prove the turbine concept on a 500kW generator.



Hydralight optical u/w mateable connector



CM2000 electrical u/w matable connector

SEA CON realised that despite its range of dozens of combinations of wet-mate and fibre optic connector types, to be a viable OEM in the marine renewable energy market it needed to develop a new, lower-cost power connector. The main requirement is for 6.6kV and 100-amp, both wet- and dry-mate connectors.

In response to this need, SEA CON (europe) Ltd, with input from SEA CON Advanced Products, LLC., of Bellville, Texas, USA, is developing a 6.6kV, 250-amp hybrid connector currently called the CM2000 HB. Purpose-designed for the marine renewable energy application, it is expected to be available later in 2014. The connector incorporates four power and four optical circuits into a single shell and will utilise existing, well-proven connection methods. It requires far less space than two individual circuits (connectors), with the additional effect of reducing the size and strength of required support structures and connection devices such as stab plates. The hybrid will be tested to withstand the demands of the projected working environment in order to ensure good long-term performance characteristics. Cost reductions will be ensured by the use of existing components, careful material selection and designing the product to be as easy as possible to install.

In order to build in some degree of "future-proofing", SEA CON is proposing to rate the product to handle more than 2MW at 6.6k VAC, or more than 1MW at 3.3k VAC. Some projects under consideration within the marine renewables community opt for a lower rather than higher voltage – this would result in the need for higher currents. Cables already proposed would generally be able to handle this without an increase in conductor size, and the reduction in operating voltage would mean higher reliability and longer life.

SEA CON is designing the connector to work at 250 amps, equating to approximately 2.3MW. Present generators are rated at around 1MW, with plans to go to 1.5MW in the near future. Therefore, the SEA CON connector will be capable of working on generators of far higher output than those presently in operation. SEA CON has adopted this strategy because it is much easier to increase current capacity than voltage.

The concept is well-defined and SEA CON is now working on detailed design, collaborating with Alstom on the project, partially funded by a UK government organisation, the Technology Strategy Board (TSB). Alstom is a large group (more than 90,000 employees), Paris, France-based global leader in the world of power generation, power transmission and rail infrastructure. Alstom acquired Tidal Generation from Rolls-Royce, UK, in 2013. Alstom's Ocean Energy business specialises in the design and manufacture of tidal stream turbines. SEA CON is supplying the hybrid connector and other parts of the connection system, whilst Alstom will be designing the hub itself and the connection mechanism.

Because it is surrounded by strong North Sea and Irish Sea currents, the UK is ideally positioned to develop both wave and tidal power. Other countries such as France and the USA are gradually coming into the picture. Most of the developers are now owned by companies outside the UK (e.g., Alstom, France, ANDRITZ HYDRO, Austria, and DCNS France) but equipment manufacture and deployment will still be in the UK.

Operating Environment	Typical Water Depth (metres)	Possible Water Temperature Range	Environmental Factors Affecting Connectors and Mitigation Strategy
Deepwater oil and gas exploration and production	Up to 3000	Constant 4°C	Water depth (mitigated by pressure compensation)
Shallower water tidal and wave power generation	(anticipated) 30 to 60	4°C to 25°C	High degree of corrosion and marine growth (mitigated by material selection and/or applied coatings)

Table 1. Connectors used in wave and tidal energy applications will work in much shallower waters than those encountered in deep-ocean oil and gas work, so they must function reliably in higher ambient water temperatures, with accompanying environmental factors

Alstom has successfully installed a full scale 1MW tidal turbine at the EMEC test site. According to the company, the turbine, which has a rotor diameter of 18 metres and weighs less than 150 tonnes, will be tested in different operational conditions off the Orkney coast over the next several months. Detailed environmental and real-life sea performance data will be generated to further improve tidal power technology and to achieve a commercial scale. The next step would be to install and monitor pilot arrays, prior to full commercial production. The turbines each operate submerged at water depths of between 35 to 80 metres, trained toward tidal direction at the optimum angle for electricity generation.

MOTIVATION AND GOALS

The market for marine renewable energy is predicted to grow significantly over the next ten years, with quantities of generators (and associated connectors) in the hundreds in a number of development areas. For example, a current project centred in Pentland Firth Inner Sound, between Orkney and the Scottish mainland, has received approval from the UK's Crown Estate for up to 400 generators, and will take advantage of some of the UK's fastest tidal currents.

According to BBC News, UK, the University of Edinburgh, UK, and Oxford University, UK, engineers have estimated that turbines placed in these waters could generate as much as 1.9 gigawatts of clean (i.e., causing no adverse environmental impact) electrical energy. This figure is equivalent to more than 40% of Scotland's annual electricity consumption, according to the news organisation.

SEA CON's overall objectives in this project are to:

- Create a reliable new SEA CON shallow-water electrical connector capable of functioning long-term (up to 25 years for connectors, although turbine manufacturers anticipate retrieval for maintenance at five- to seven-year intervals) at approximately

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50% of the cost of currently available deep-ocean wet-mate and fibre optic connectors, without compromising performance. SEA CON expects to achieve this by applying existing connection methods – i.e., the proprietary underwater mateable CM2000 electrical and Hydralight fibre optic connectors.

- Provide a product specifically designed for the marine renewable energy environment.
- Build in the flexibility to allow the product to be used in later generator versions.

CHALLENGES

Connectors used in wave and tidal energy applications will work in much shallower waters than those encountered in deep-ocean oil and gas work, so they must function reliably in higher ambient water temperatures, with accompanying environmental factors, as shown in Table 1.

Corrosion resistance can be achieved by the use of high-specification materials such as titanium or Super Duplex stainless steel, but this comes at a cost. Marine growth is more difficult to combat without the use of environmentally unfriendly materials, so is by far the most difficult challenge to mitigate. Both corrosion and marine growth must be controlled in this environment by material selection. Although the oil and gas industry is fully developed and many contractors are able to afford the high costs of the most advanced connectors and cable termination devices, the marine renewables community cannot afford these costs.

In both wave and tidal energy generation, water oxygen content is constantly refreshed – a phenomenon not as prevalent in deepwater; this refresh encourages corrosion and marine growth.

In relatively shallow waters, wave and tide variations cause continuous pressure cycling. This phenomenon will have some effect on the sealing of the connectors.

The power generated by the marine renewable energy generators is not constant. Wave power levels are constantly varying and tidal power goes from zero to maximum twice per day. This must be considered as a potential problem and appropriate testing carried out.

In order to make the arrays commercially viable, it is important that the individual generators can be installed and retrieved for maintenance or repair with minimum effort. This includes a reliable method of connecting and disconnecting the electrical and fibre optic cabling.

Costs of the connectors are mainly driven by the high-specification materials used, including the need for protection when un-mated in the subsea environment, the level of testing and qualification required and the comparatively low quantities that are ordered at any one time.

The marine renewable industry sector requires products that will work as well (and as long) in a harsher environment than those used in the oil and gas sector, but at a far lower cost. To achieve this, the connector industry needs both quantity and, most importantly, standardisation.

Quantities in marine renewables at present are very low, since most requirements are for prototypes. It is possible in these applications to utilise connectors with lower-grade materials and of less-advanced design, as the deployment times are much shorter. However, serious marine growth and corrosion have been seen even after periods of only a few months. Even with the first array installations, quantities will still only be quite small, so it will be difficult to reduce costs significantly.

CONCLUSION

The factor that will serve to bring the greatest reduction in cost will be standardisation of ways to reduce variations in current, voltage, numbers of contacts, cable types and test requirements. The oil and gas industry has introduced a number of specifications which have allowed connectors to be procured from a number of manufacturers with confidence that they will perform to specification. These industry-standard specifications have been developed by both the major users of the products, the oil and gas companies themselves and Joint Industry Projects (JIP) with the same objectives.

For the connector industry to be able to produce what is needed for marine renewables, a JIP involving connector manufacturers, generator developers and installation contractors would be very useful in addressing the priorities of all stakeholders.

Although the state-of-the-art is continually improving, the marine renewables market is still immature. But, thanks to funding by the UK government and other organisations, as well as international scientific and engineering collaboration, obstacles to full commercialisation of wave and tidal power generation are gradually being reduced.

David Pye has 24 years of experience in the international subsea connector business. He holds a Higher National Diploma in Mechanical Engineering. His career includes: six years as a mechanical engineer (including a five-year engineering apprenticeship) at Rolls Royce Aero Engine Division, Derby, UK; 14 years as an engineer at Slingsby Engineering, the manufacturer of ROVs and associated products; similar positions with various subsea connector manufacturers; and the last four years with SEA CON working exclusively in the marine renewable energy field.

Michael Mulcahy is a former US Navy officer and former *Sea Technology* magazine managing editor. He has written more than 100 ocean science and engineering articles. His interests include undersea connectors and cables, marine engineering, naval architecture, commercial diving, ROV operations and ship salvage engineering. He is a graduate of the University of North Carolina at Chapel Hill, USA.