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Reliable turbines for Tidal and River uses

In the latest edition of our newsletter, LRI interviewed Pieter De Haas, Chief Technology Officer at Tocardo Tidal Turbines. Tocardo have demonstrated their 100kW turbine in the marine environment. This is now ready for deployment in commercial tidal energy projects. A 500kW turbine is undergoing development and testing and is expected to be available in 2015.

Who is Tocardo?

Tocado is a Dutch tidal technology company with regional offices in Canada and the UK. The company has formed strategic partnerships with the oil & gas company Repsol, manufacturing companies Strukton and Huisman, and carbon credit and route to market advisory company Climex. Tocardo has several demonstration projects in the Netherlands and has acquired its first clients from Asia.

Tocado Turbine technology

Tocado's turbine is designed to be installed in rivers and in near shore environments exposed to tidal streams. Electricity generated by the turbines can be exported to the grid or used in off-grid applications.

Two key principles underpin the turbine's design:

- 1) Minimising the number of moving components in the device to drive down O&M costs resulting from component failure.
- 2) Creating a scalable design. Scalability ensures that sudden, non-linear cost increases do not occur as

the capacity and physical size of the installation increases. In principle, the Tocardo turbine is scalable to 1.5MW.

Timeline

The Tocardo concept was developed by Teamwork Technology, an incubator for renewable concepts such as energy, transport and housing.

1999 - Teamwork Technology conducts testing with the Venturi tidal energy converter design.

2002 - After concluding the Venturi design was not a viable option, Teamwork Technology conducted testing with the Ring Generator design.

2005 - Teamwork Technology concludes the Ring Generator design is not scalable and would suffer from high O&M costs. Teamwork Technology moves on to test the two blade horizontal axis turbine design, which is the basis for the Tocardo turbine.

2008 - Tocardo Tidal Turbines becomes independent from Teamwork Technology and complete the operational testing of a 40kW uni-directional turbine in the marine environment.

2011 - Tocardo completes the operational testing of a 100kW turbine with bi-directional blade.

2013 - Initial testing of turbine array at Afsluitdijk begins; full-scale offshore testing of T100.

2014-15 - Completion of R&D testing for T500 turbine (rated output 232-520kW), and installation of 500kW turbine for operational testing.

2015-16 - commercial (<5 MW) demonstration projects implemented.

2018 - 10MW commercial arrays ready for order.

2023 - 100MW commercial arrays ready for order.

System Design

The device is a horizontal axis, bi-directional turbine, with two fixed (as opposed to pitched) blades. The blades are connected on one shaft through the nacelle instead of using separate individual connections, which reduces O&M costs. The turbine converts tidal energy through a direct drive system, which precludes the need for a gearbox. The 100kW and 200kW units have dry weights of 6.5 tonnes and 14 tonnes respectively. The turbine is bi-directional, and operates in two positions which alter depending on the direction of the

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tide. Superficially, the turbine looks like it has a pitching blade, but instead has an axle connecting the blades through the nacelle. To increase reliability Tocardo has sought to reduce the amount of electronic components in the design. The necessary components for conditioning the electricity and stepping up to export voltage are secured in a dry box. In the case of turbine arrays, there will be an offshore substation where the electricity generated by each individual turbine is aggregated.

Tocado's simplistic design means that the turbine can be scaled up or down without the need for redesigning multiple parts. This was achieved through the testing of multiple designs and minimising the number of separate components as far as possible.

Installation

Tocado's CTO, Pieter De Haas, expects the first commercial projects (approximately 10MW) will use buoyancy structures. These foundations are relatively easy to install and require fewer permits than seabed foundation structures.

In addition, buoyancy based foundations allow a relatively easy recovery of the turbine, which is significant for reducing O&M costs. Turbines can also be mounted beneath existing structures such as bridges or piers or attached to a floating platform.

Pieter De Haas suggests that the larger projects (in the region of 100MW) will use seabed structures. Buoyancy based foundations become a less viable option for large projects for several reasons:

- 1) Vulnerability to storms means that maintaining a large number of buoyancy based foundations could lead to unviable O&M costs.
- 2) The installation of a large number of buoyancy foundations requires complicated mooring and anchor patterns, which are difficult to group in close proximity.
- 3) The top of buoyancy foundations appear above the water surface, presenting a potential visual and navigation issue when deployed in large numbers.

Tocado are planning for their first commercial scale projects to have foundations that hold between 1-2MW of turbine capacity. Depending on the model of Tocardo turbine used in a project, this could be between 10-20 100kW units, or 5-10 200kW units on the first commercial scale projects. Eventually, it is likely that tidal energy projects will consist of devices with far



Tocado T100 installation (images courtesy of Tocardo).

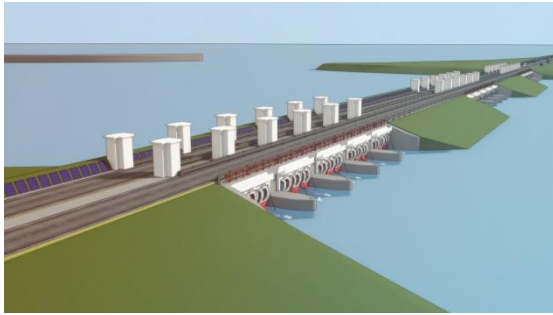
larger capacities that are deployed in fewer numbers. The deployment vessels for the 100kW and 200kW installations are small in size, possess a deck crane and are common and conveniently available in most harbours and docks.

This availability and relative cheapness of small vessels is one of the factors behind Tocardo opting to design a relatively small turbine size. No bespoke equipment is required for the installation of the turbine, which also minimises costs.

Maintenance

During testing, Tocardo has managed to achieve very low O&M costs for their turbines. For example, their 2008 40kW demonstration turbine has experienced no downtime to date. Pieter De Haas expects this to be replicated in commercial projects using Tocardo turbines.

The only scheduled maintenance prescribed by Tocardo is an oil change, which should take place every 5-10 years for a 20 year project. Repsol, one of Tocardo's partners are in the process of developing oil that will last 20 years. The turbines do not require onsite inspection because monitoring software provides all of the relevant information on the operational integrity of each unit in a project.



100kW turbine operating in Den Oever, Netherlands (images courtesy of Tocardo).

Business Model

Although Tocardo is traditionally a technology developer, the company has gained valuable experience in the technical aspects of project development, including site assessment, project cost analysis and project financing. With the help of its strategic partners, Tocardo is able to assist prospective clients to develop a complete project.

Applications

Offshore environments are the preferred setting for large and commercial turbine arrays producing up to 100MW. Approximately 1 to 3.5 miles offshore is optimum due to the diminishing power of the tidal stream beyond 3.5 miles. Once the number of turbines in an array is large enough it is beneficial to use seabed foundations instead of buoyancy structures. This requires more permissions and set-up time but will reduce O&M costs compared to a large buoyancy structure.

Near Shore environments suit Tocardo's 200kW model which has a blade diameter of 4.5m to 9m. The clearance required is 1.5m below and 1m above the turbine at low tide, meaning this model could be installed approximately 0.5miles offshore. While shipping traffic has the potential to restrict installation in such environments, many locations will provide sufficient clearance for both turbines and shipping at this distance offshore.

Rivers are a reliable and convenient source of energy for the smaller Tocardo turbines. Small turbines located in rivers or near shore environments are believed to be the strongest use of Tocardo turbines. The 100kW model is predicted to be popular given its small scale and 6.5 tonne dry weight. This could supply electricity to remote communities without the need for expensive grid connections. The LCOE is comparable with a diesel generator.

Ready to order

Turbines up to 200kW are now ready to order and deliverable within 6 months. Tocardo received 11 orders between January and May 2014, and they are ready to receive enquiries from potential customers.

These turbines have competitive LCOE and can be installed in an extremely diverse range of locations. 500kW turbines are currently under testing and are likely to be available in late 2015.



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Summary

- Tocardo turbines can be used globally wherever there is a flow of above 2m/s.
- Small turbines are available for river based projects capable of supplying low cost energy to remote communities.
- Simple design allows scaling without incurring redesign costs.
- Turbine blades turn both ways to maximise tidal power generation.
- Low O&M costs: the only necessary maintenance is an oil change every 5-10 years.
- Minimal electronic parts mean high reliability and an increased lifetime.
- Tocardo are ready to receive orders on the smaller models and are currently developing the larger, commercial range of turbines.

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