Marine tidal turbines are getting close to reality and potentially taking over from wind generation, even nuclear power plant. Brian Tinham talks to engineering pioneers

Turning the

While wind farms, for most of us, are the iconic, if not entirely friendly, face of renewable energy, there's a quiet revolution readying itself for launch on an unsuspecting public. The new talking point will be marine turbines. Not only could they challenge wind, but also nuclear plants – and soon. As we go to press, a full-scale commercial marine turbine, designed to harness tidal energy, has been installed and commissioned on the Irish coast, and is undergoing final tests before running up initially to 1.2MW electricity generation.

Why is this so interesting? Primarily because of the technology's huge potential, not just for large-scale, reliable generation, but, importantly, also for its base load capability. Best projections already indicate that marine turbines, dotted around the UK coastline, could make a significant contribution to replacing the current nuclear capacity in this respect – and at vastly less cost and risk. Achievable technological advances, combined with the development of a sound commercial infrastructure, geared to marine turbine production and installation, appear to be the only remaining barriers to turning this dream solution into reality.

So let's take a look at the facts, before we get on to the engineering challenges, the state-of-the-art and specifically the plant now going online. Hot spots around the UK, capable of providing adequate tidal flows, are numerous – ranging from the Isle of Wight and Portland Bill, to the Bristol Channel, off Anglesea, the Isle of Man, the north east coast of Northern Ireland, the west coast of Scotland and the Pentland Firth, between Scotland's north coast and the Orkneys. Some look better than others, not only for their flows and local environment, but their existing grid connections – for example, Pentland Firth is near the Douneray

Photo courtesy Dr I J Stevenson

nuclear power station, while Anglesea has Wylfa.

Even taking into account today's relatively early stage technology, building tidal turbine farms on the more benign sites could lead to 7GW of generation, according to Angela Robotham, engineering director of Marine Current Turbines – the company responsible for the first commercial demonstrator unit, currently under test in the Strangford Narrows, on the Northern Ireland coast.

"If you picked just nine sites from BERR's [formerly DTI, the department for Business Enterprise and Regulatory Reform] published tidal maps – and that's only 3% of the total tidal resources – you can take that up to 14GW, which is way above the government's target of 2GW from renewables. It's also far in excess of the UK's approximately 11GW of nuclear generation capacity. And, unlike with wind generation, we can predict the tides for the next 200 years."

What about installed cost? Currently, it's working out at around £2,500 per kW, she says, but the mid-term goal is to take that down to £1,000 per kW – which is where offshore wind is going.

And visual impact? These units resemble small, very low profile lighthouses, so it's limited: a point proven three years ago by Robotham's firm. The company used Autodesk 3D CAD (computer aided design) software to superimpose its proposed turbine structure on the landscape at the mouth of Strangford Loch – and comfortably sailed through the local planning process, even though this is a designated site of special scientific interest (SSSI).

tide

What about the base load claim? "The beauty of tidal energy is that tides don't flow at the same time at different longitudes. So when some locations are slack, others could be providing energy," she says. "So, if you can achieve sufficient margin over the power that nuclear provides today, marine turbines could fulfil the base load requirement in a way that wind farms just can't."

She concedes that we need feasibility studies around electricity transmission, as well as an infrastructure building programme – but compare that to the issues and costs of a nuclear restart.

Engineering limits

So what are today's limits? Robotham says the current generation of turbines operates best in tidal areas offering depths of 20 to 28m. That leads to two issues – one concerning the steel structure that supports the turbine, the other the plant and equipment to install it. "The world's fleet of jack-up vessels is almost entirely in use installing wind farms so, late in development, we had to resort to a crane barge, which meant a move away from a monopile to a quadrapod and steel tower. So we need more installation resource, but also work has to be done on second-generation technology, so that these machines can go into greater depths of water."

As for the plant itself, it's come a long way since the experimental marine turbine erected on a pontoon at Loch Linnie on the Scottish north coast in 1994. That was a proof of concept development, led by IT Power, and, despite a marked lack of government or industry investment – probably due to the then success of North Sea oil and the 'dash for gas' CCGT (combined cycle gas turbine) period – R&D has picked up in recent years.

In 2003, Marine Current Turbines' prototype SeaFlow machine was installed in the Bristol

Pointers

- Marine tidal turbines could yet challenge wind farms and nuclear power for base line generation
- SeaGen has two powertrains, each designed to provide 600kW at 2.5m/sec tidal flowrate
- Engineering and surface treatment know-how follows marine and offshore oil experience to date
- Marine Current Turbines has developed innovative levelling and installation techniques
- The developers believe they have engineered reliability and safety into this third generation plant

Left: SeaGen installed at Strangford Below: the crossbeam and rotors under construction

Channel, just off Lynmouth. That revealed data about aspects such as efficiency and power curves, how tides interact with different turbine blade profiles etc – verifying CFD (computational fluid dynamics) software calculations not only on the rotors, but also the crossbeam structure carrying the dual engines, and promoting further development.

And now we have SeaGen, the company's latest iteration, installed at Strangford, taking in the resulting enhancements. Essentially, we're looking at a steel tower and box-section crossbeam wing, with leading and trailing edge fairings, fabricated from glass composites, supporting two powertrains – one either side to encourage approximately symmetric forces on the tower structure. Total weight, including concrete ballast, is about 1,000 tonnes and the unit is sitting in 25 metres of water. The rotor blades are built from a carbon spar and glass composite skin and, although the powertrain and braking technology is conventional, many components were bespoked, including the seven-metre blades and the hubs.

Live and generating

So there you have it: SeaGen generated 200kW on 16 July, before the current testing and verification phase, and the only thing in the way of progress is infrastructure, imagination and political will. Infrastructure, because manufacturing and marine industry isn't geared up for large-scale build and deployment – the latter having already been swamped with wind farm installations. But there are also material issues: for example, taper roller bearings of the size required – which are much the same as for steam turbo generators and wind turbines – are currently on 15–18 month lead times.

That said, when the Strangford unit is fully operational, Marine Current Turbines expects to turn its attention to Anglesea for the first commercial marine turbine farm. "We're already running site investigations and we believe we can build 150MW capacity in the space available. We could have up to 1,000 SeaGens at other sites, and the next generation will be built with longer rotor blades and designed for deeper waters, say 100m.

"Currently, we're proving to ourselves, investors and manufacturers that the concepts work. It's a long-term project that may yet see us leasing technologies to big system integrators and builders. This country needs to build up an industry capable of supporting this endeavour – just as wind energy plant is built and installed today. UK plc has to decide what it wants to do: We're already in grave danger of losing manufacturing to foreign suppliers. We just hope UK industry can keep up." PE

Plant engineering in action

As for the engineering detail, Angela Robotham first makes the point that the powertrains are sized to operate optimally at about 60% of maximum predicted tidal flowrate, each providing 600kW at 2.5m/sec flow. "That keeps the component size and cost down, and also means we can generate at rated capacity for much greater periods of time than if, say, plant was built to handle peak flows. We've developed mechanisms to safely discard energy above rated capacity, mostly using blade pitch control [also used to enable energy collection in both tidal directions], and we're currently testing the algorithms for automating that."

Then there's surface treatment for the rotors. Currently, both wind and sea turbines are effectively smooth, although the latter use standard marine anti-fouling coatings. In fact, much of the engineering know-how stems from marine propulsion technology. However, although smooth surfaces are conventionally accepted as presenting minimum drag, Robotham indicates that research is now borrowing from nature – and in particular shark skin – observing that setting up a fine turbulent boundary layer can reduce overall friction at the rotor blade surface, thus improving efficiency and energy collection.

Next, deployment of the structure – and one of the successes here concerns the levelling system. "You can survey the seabed to your heart's content, but you don't know the exact topology, so we developed a levelling system, using large hydraulic cylinders attached to each of the four feet and linked to a display. That quickly stabilises the structure under its own weight, prior to fixing it down with pin piles and high-strength grout on the following tidal cycle." That's important, because it's one of the keys to making future large-scale installation possible, since it allows the whole operation to be carried out largely irrespective of weather conditions.

What about access? "We've learnt to position access ladders such that a rig can be reached safely, even when the tide is running. We've also installed fall and arrest systems, so that engineers can just clip on and stay safe. Once they're on the working platform, it's a safe environment and, in the control room on top, it's also weatherproof."

As for the question of reliability, Robotham suggests that – beyond good engineering design, assembly and installation practice, as well as quality management procedures – key issues concern factors such as sensor and connector choices, and sealing techniques. "It's about paying attention to the marine environment, and ensuring that instrument signalling is robust and that you use techniques such as double-sealing on hatches, while pressuring internal cavities around, for instance, the powertrain," she says.

And there's the lifting system: "As of today, it is important to be able to gain access to the powertrains for inspection and maintenance. As reliability is proven that may well not be the case, but for now we're using a hydraulic system automated under PLC control to bring the crossbeam and rotors from their subsea operating position to clearing the water surface. Then engineers can walk safely along the crossbeam with the usual fall prevention systems to work on the powertrain, inside the power hubs and so on."