Discrete Automation and Motion

Marine renewable drive train system
Narec engages ABB for Nautilus test facility

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Cost efficient testing of marine renewable devices

The challenge

The marine environment is extremely challenging and deploying marine renewable devices is costly, time consuming and highly weather dependent. Companies seeking to exploit offshore renewables need to be able to reduce product costs and development cycles while increasing device reliability within acceptable timeframes.

The UK government recognised that if developers are to be able to prove that their devices work reliably before they are deployed in the open water then a test facility that recreates the loadings that the devices will see in service is necessary.

The solution

As part of the Low Carbon Transition Plan, Narec (National Renewable Energy Centre), located in Blyth, Northumberland was awarded funding to build a €15.4 million, 3 MW tidal turbine drive train test facility. Project Nautilus is the world's first drive train test facility dedicated to the requirements of the marine renewables sector and aims to remove the risks associated with in-field power generation.

The facility allows Narec's customers to perform accelerated lifetime testing of new tidal power generation devices in a controlled onshore environment. "We can replicate, on demand, about six months of tidal conditions that you would otherwise have to wait a couple of years to occur within the actual environment," says Tony Quinn, Operations Director, Narec.

The 3 MW drive system is capable of testing the complete drive train, electrical generation, control and support systems of marine renewable devices. Based around the existing dry docks, there is no comparable open-access R&D facilities elsewhere in the world.

"Nautilus accelerates the deployment of renewable technology thus gaining investor confidence and helping the devices towards commercialisation," says Quinn. "We can run tidal turbines, for instance, through some very demanding simulated operating environments in a relatively controlled, benign environment. It's about robust testing but it's also about the team of engineers here that are able to analyse and help that innovation and design. You will not see anywhere else in the world a concentration of test facilities of this scale and magnitude or indeed their comprehensive nature."

Atlantis Resources Corporation's AR1000 nacelle is the first tidal turbine to be tested at the Nautilus facility (see front cover). Below is an artist's impression of an array of Atlantis AR1000 tidal turbines.

Reducing in-service failure risk

Technical solution

The Nautilus test facility allows the key components and assemblies including drive shafts, bearings, gearbox, generator and power converters, to be thoroughly tested in order to evaluate performance and optimise reliability prior to actual subsea deployment. This significantly reduces the risk of in-service failure of the key electrical and mechanical components used within tidal stream turbine technologies.

The test facility can mechanically and electrically load the complete drive train with the full envelope of loads, including side loads on to shafts and bearings.

The facility performs turbine testing in accordance with IEC and ISO standards or customer requirements. The facilities will achieve ISO17025 accreditation by The United Kingdom Accreditation Service (UKAS) once certification standards for controlled environment testing are finalised.

Commercial solution

The major components have been procured by Narec through a rigorous public procurement procedure, in order to provide a test facility that is capable of delivering extremely onerous test regimes.

"Public funding requires a demanding procurement procedure and ABB won the competition for the motor, drive and electrical equipment based on price, quality, delivery and technology," says Dave Southern, Principal Project Manager, Narec.

ABB was chosen for the project because it could supply a complete turnkey package of drive, motor, switchgear, ancillary equipment and the portable equipment buildings to house them. The company also has a proven track record of using this type of drive in similar test facilities.

"We have been really pleased with ABB's performance," confirms Tony Quinn, Operations Director, Narec. "Projects of this nature are rare; they are one off in terms of scale and technicalities. It takes a very special team to pull together and overcome the inevitable hurdles. ABB, with its extensive knowledge of test facilities and one-off projects, provided an exceptional project management team: they were positive, nimble and reactive. As Operations Director, my job is to get involved when things go wrong. I did not have to get involved with ABB at all."

The test hall houses the 3 MW turbine drive train test rig.

Nautilus test facility

Key characteristics

– 3.25 MW input motor to drive the device under test
– 20:1 reduction gearbox
– Force application system (FAS)
– Grid connection
– 516 channels of data measurements
– Max. bending moment applied by the FAS – 15 MNm
– Max. continuous torque 5 MNm (0 to 6 rpm)
– Max speed of device under test - 30 rpm
– 125 tonne overhead crane capacity

Typical testing activities
Rather than test individual components, Nautilus tests entire systems including the turbine, generator and power converter. Being able to observe how the entire system works in conditions that replicate the real environment, is far more cost effective than testing individual components.

"We need engineers not to test components but to test the system," says Quinn. "This will go a long way to the ultimate aim which is to lower the cost of energy. Nautilus embraces the concept of learn by doing and does this by providing the ability to accelerate the learning curve. This way you can reduce costs of energy much quicker. Nautilus allows you to accelerate your learning and rapidly reduce your cost of electricity. The biggest single contribution is to drive the technology as quickly as you can through the bath-tub curve to make it commercially viable and investable."

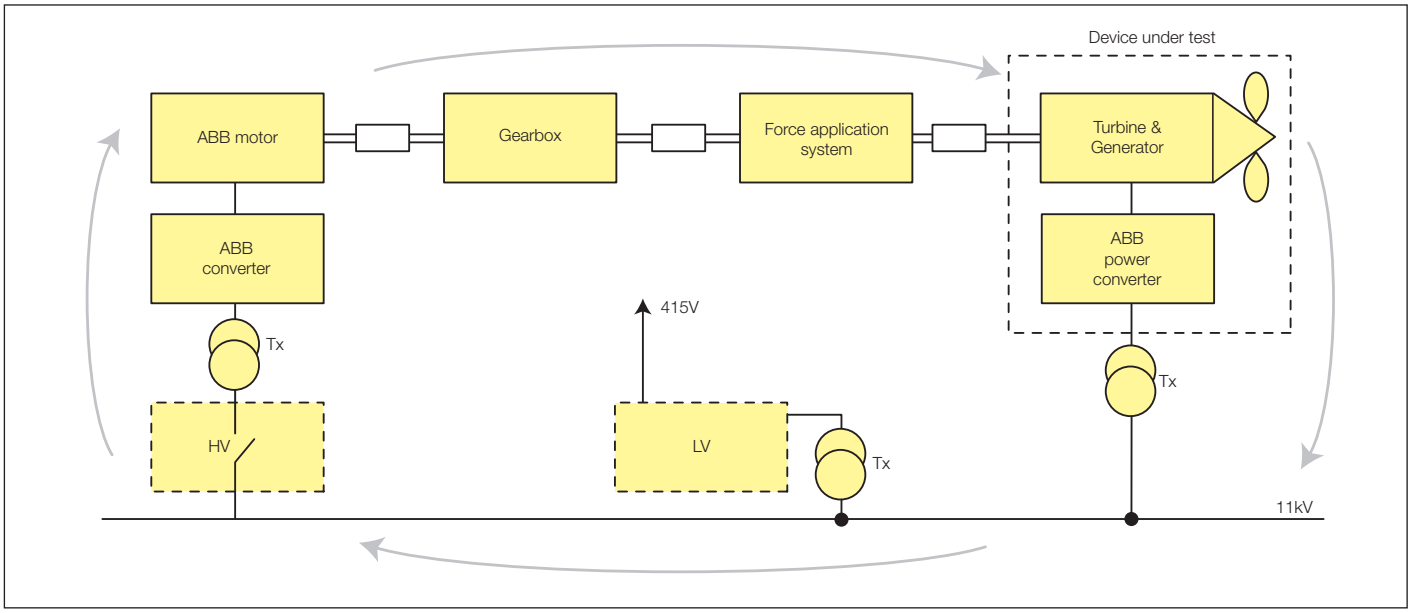
As an integrated electrical and mechanical test facility, Nautilus is designed to undertake a wide range of testing including:

Research and development

– Prototype testing - system or major component within system
– New supplier validation testing - major component
– Internal manufacturing conformance testing - system or major component within system
– Improvements to models physical and numerical – condition monitoring validation
– Component validation and conformance testing

System performance and endurance

– Axial and radial force application and bending moment application to emulate operational conditions
– Bearing durability
– Brake emulation
– Condition monitoring
– Control system validation tests and design verification
– Control strategies
– Cold starts
– Dynamic torque
– Electrical overloading - controlled percentage
– Emergency stops
– Mechanical fatigue loading
– Overall system 'highly accelerated lifetime tests' (HALTS)
– Unbalanced rotor
– Power curve assessment
– Shaft rpm run away
– Thermal evaluation
– Turbulence induced forces
– Wave induced forces



Scope of supply

Test hall

The steel structure of the test hall is 15 metres high and is constructed over an existing dry dock. The dry dock needed three mass concrete pours to cover an area of 45 x 15 x 6.5 m (approximately 7,000 m^3) and is reinforced with a high grade steel lattice to withstand the weight of the frame and rigorous testing procedures.

Designing a foundation to take the extreme forces presented by the systems under test demanded the best engineering skills available. Nautilus is designed to allow tidal generator systems to be tested either within the hall or directly from the dock. To enable this, the motor, gearbox and the force application system (FAS) can rotate through 180 degrees. The 4m x 4m bedplate on which these items sit, allows positioning with an accuracy of 0.2 mm, compared to normal civil engineering tolerances of 5 mm.

ABB motor

A 12-pole 3,256 kW, water-cooled ABB motor acts as the prime mover in the test facility. The motor, which weighs almost 60 tonnes, is designed to develop a high torque with impressive speed accuracy to meet the demands of the test programme. The motor uses hydrostatic bearings and a lubrication and jacking system is incorporated into the motor pedestal.

Motor	
Power	3,256 kW
Pole	12-pole
Constant power	120 - 600 rpm
Constant torque	0 – 120 rpm
Cooling	Water
Type	Low speed, high torque, double wound

Gearbox

A 20:1 David Brown reduction gear box develops output shaft torque and rpm characteristics that represent the ranges typically experienced by tidal stream drive train systems.

Gearbox	
Max. continuous operation torque	5 MNm
Max instantaneous torque	10 MNm
Shaft speed at max. torque	6 rpm
Speed range	0 – 30 rpm
Direction of rotation	Bi-directional

ABB's 3,256 kW water-cooled motoring.

ABB supplied low and medium voltage switch gear.

Scope of supply

Force application system (FAS)

A MTS-manufactured force application system (FAS) acts as a special coupling that applies forces to the turbine shaft in the axial, horizontal and vertical directions to simulate the characteristics and forces experienced with tidal flow.

The functionality of the FAS is key to the Nautilus test facility and differentiates it from conventional 'back to back' rotary test facilities. The FAS applies the typical and extreme forces and moments that the marine environment will exert on a tidal turbine device in service.

There are a number of occurrences that introduce non-aligned loads and bending moments into the input shaft of a tidal stream turbine. Examples of these include turbulence in the incident flow, yaw misaligned to the flow and more extreme events such as blade failure. More specific to the marine environment are wave induced water particle accelerations.

The FAS is designed to be able to replicate these transient forces in order that the devices under test are subjected to realistic in service environmental loadings.

The FAS introduces its forces and bending moments via a series of hydraulic rams that act upon a floating shaft coupling such that the drive shaft is physically displaced. The coupling is designed to not transfer these loads and bending moments back into the Nautilus gearbox and motor.

Force application system	
Max. bending moments	15 MNm
Max. radial loading	4 MNm
Max. axial loading	4 MNm

ABB medium voltage drive

ABB's ACS 6000 is a modular medium voltage AC drive system that can be configured in single or multidrive solutions on a common DC bus. The ACS 6000 is designed for demanding applications such as the Nautilus application. The 3 MW drive system for Nautilus features a 24-pulse input rectifier for low harmonics. This feeds a common DC bus to which two 11 MVA rated inverter sections are connected. The two inverter sections feed the prime mover motor double winding. A braking chopper is also connected to the DC bus. This allows fast braking of the test facility and device under test in the event of a process or emergency stop requirement and allows energy to be dissipated from the test facility in the event of a mains network power outage. The high power density and compact design and the drive's communication abilities minimise the overall installation and operational costs.

ABB's DriveMonitor™ system is fitted to the ACS6000.

Medium voltage AC drive	
Type	ACS 6000
Cooling	Water-cooled

DriveMonitor™ is an intelligent monitoring and diagnostic system and provides secure access to the drive from any location in the world. It allows real-time access to the drive, providing early detection of faults and thereby helping avoid costly repairs.

ABB switchgear

ABB also supplied medium and low voltage switchgear, oil filled input transformer, three oil filled distribution transformers and two portable equipment buildings to house the ACS6000 variable-speed drive, low voltage and medium voltage switchgear.

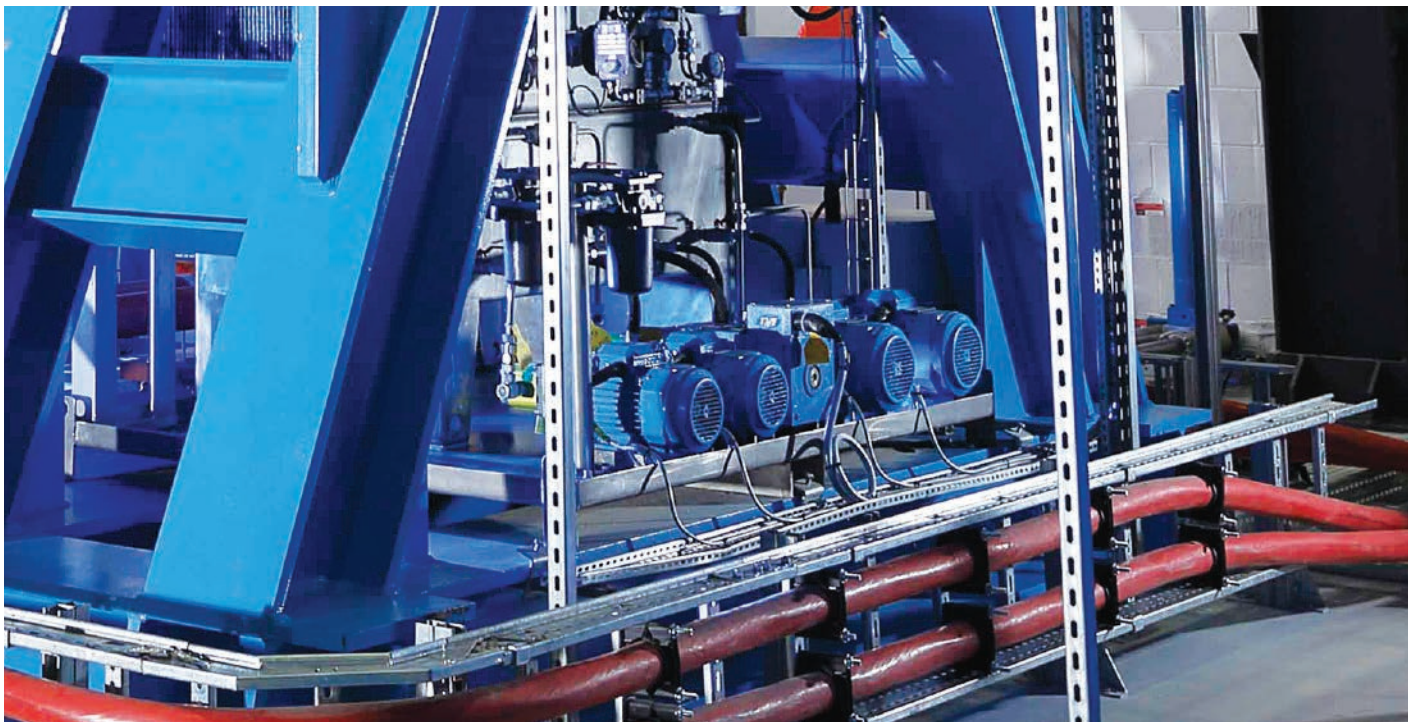
The ACS 6000 medium voltage drive is housed in a separate electrical container.

Benefits to the test facility

The benefits

– World's first drive train test facility dedicated to requirements of the marine renewables sector - significantly reduces risk of in-service failure of key electrical and mechanical components used within tidal stream turbine technologies.
– Facility performs accelerated lifetime and "extreme event" testing of whole turbine nacelles and individual drive train components of prototype tidal power generation devices.
– Simulates environmental loads likely to be experienced by a tidal device offshore - reduces financial risk and improves reliability for developers, before full demonstration and deployment at sea.
– ABB able to supply complete turnkey package of drive, motor, switchgear, ancillary equipment and the portable equipment buildings.
– Proven track record of using ACS 6000 medium voltage drive in similar test facility applications.
– High power density and compact design and drive's communication abilities minimise overall installation and operational costs.
– DriveMonitor™ allows real-time access to drive, providing possibility of remote diagnosis and system monitoring by the customer or ABB service or technical staff from any location in the world.

Motor lubrication and jacking oil system mounted within the motor pedestal.



Contact us

About Narec

Narec (National Renewable Energy Centre) (www.narec.co.uk), is a UK centre for renewable energy and low carbon technologies. The centre develops prototypes, tests renewable devices to international standards and is involved in installing low carbon technologies. It is very similar to other centres, such as NREL in the US and National Centre for Renewable Energies (CENER) in Spain. Narec is based in Blyth, Northumberland.

As a key driver of the national agenda, Narec is creating a world-leading technology advancement hub for the offshore renewables industry. This involves working with global turbine, blade, electrical infrastructure manufacturers and project/device developers on their large turbine, blade and associated equipment development programmes. Narec also acts as an advisor and consultant to utility companies, industry, network operators, project developers and OEMs.

About ABB

ABB (www.abb.com) is a leader in power and automation technologies that enable utility and industry customers to improve performance while lowering environmental impact. The ABB Group of companies operates in around 100 countries and employs about 145,000 people.

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