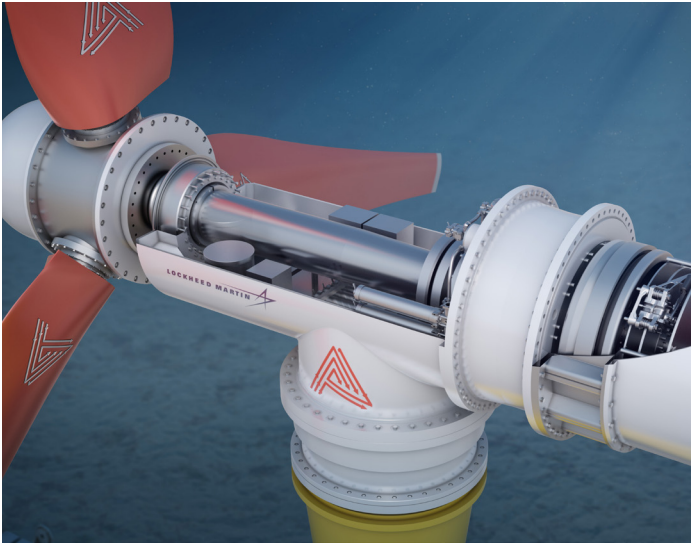




AR1500 TIDAL TURBINE





The AR1500 turbine is designed for simplicity and reliability to achieve extended intervals operating underwater without intervention

TURBINE

The turbine has multiple levels of redundancy within its system, allowing continued operation even if some faults occur. A comprehensive condition monitoring system allows the prediction of failure and planned maintenance as necessary. The turbine is designed for a 25-year life, with three services in that period, at 6¼ year intervals. Total mass of the unit is 150 tonne in air, placing it within the capacity of more readily available DP (dynamically positioned) construction vessels for installation and retrieval.

BLADES

Blades are a critical part of a turbine, as they capture the energy of the flowing water and deliver it to the hub. High speed tidal current flows contain a lot of energy, which means that tidal turbine blades are highly loaded, and turbulence in the flows means the load varies continuously. Consequently, blades need to be not only an efficient shape, but also very strong. The AR1500 blades are formed in two halves made from carbon fibre 'skins' which both give the foil shape, and carry the loads. This efficient structure means that the blades are relatively thin - which results in better hydrodynamic performance for the rotor,

lighter weight and improved cost effectiveness. The blades are fitted to pintle shafts on the hub, located with a cross-pin in an arrangement that can be mounted and dismantled very quickly.

The outside casings of the integrated gearbox and generator are in direct contact with the seawater so that both are passively cooled by water flowing past them ensuring increased life for the components. This is simple, but effective, and means they run at low temperatures without the need for more regular maintenance that would be necessary with active cooling systems.

HUB & PITCH SYSTEM

From the low currents at which the turbine can start up to its rated current, the blades are held at a fixed pitch angle. Above rated current, the blades are progressively pitched to shed energy and maintain the turbine at rated power. The AR1500 pitch system is hydraulically driven; the actuation system is self-contained within the dry hub. The system is collective, so that a single actuator drives all three blades at the same time; much the same as variable pitch marine propulsion units are actuated. This reduces the number of components in the system, and means that multiple levels of redundancy can be incorporated, all increasing total reliability.

Base-case architecture already proven

Tidal power

Tidal power is a predictable source of clean energy generation, making use of mature technologies developed by the oil & gas and wind industries over the past two decades.



ELECTRICAL SUBSTATION

Why underwater?

■ **Space saving, no visual pollution**
An underwater turbine with 9 metre blades can generate the same power as an onshore wind turbine with 30 metre blades. Low environmental impact with slow rotor speeds.

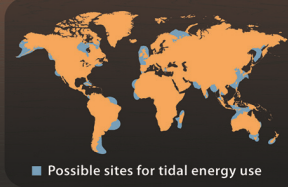
■ **Steel turbine nacelle with composite rotor blades**
■ **Total weight (incl. foundation) ~ 1,000T**
■ **Each turbine can generate enough electricity to power around 1,400 homes**
■ **Each nacelle takes approximately 90 minutes to install onto a pre-installed foundation, offshore**

More predictable

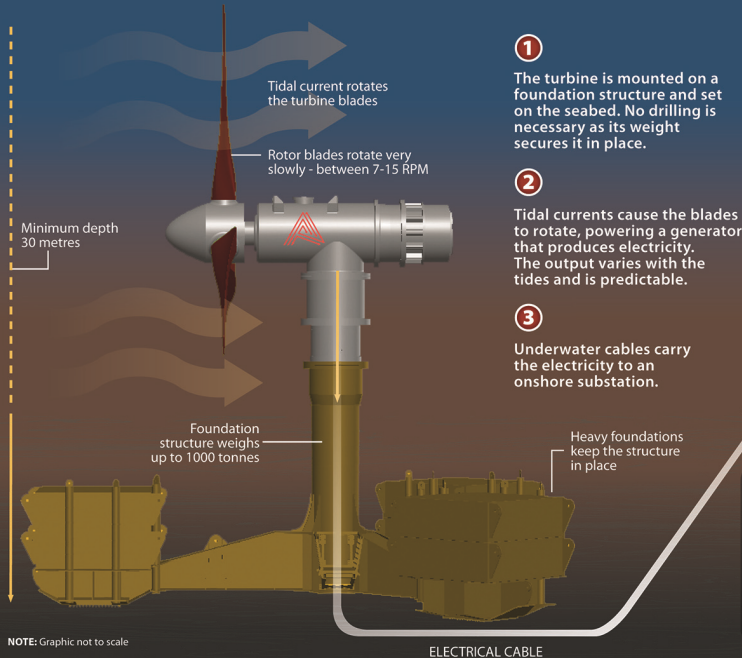
Unlike wind and solar energy, tidal energy is predictable as tidal currents can be accurately forecast years in advance. This makes for a more reliable source of electricity generation.

Large untapped resources

Water covers about 70% of the world's surface and every continent has potential sites for harnessing the power of tidal currents.



■ Possible sites for tidal energy use



GEARBOX & GENERATOR UNIT

The gearbox is a 2-stage, epicyclical design using flexible planet pin technology to produce a product that is tolerant of both shaft deflections and shock loads. This makes the whole drivetrain robust and insensitive to movement of the nacelle and shaft under load. The gearbox has a redundant, pumped oil lubrication system that ensures good cooling and lubrication of all the gear meshes and bearings.

The generator is integrated with the gearbox, with the generator rotor supported by the gearbox output shaft bearings. This means there are no independent generator bearings, and the whole rotating unit is covered by the same, high-capacity lubrication system. The generator is a permanent magnet type which operates at high efficiency over a wide speed range.

MAIN SHAFT & BEARING

The hub mounts on the flange of a shaft that supports the rotor and transmits the torque to the gearbox. The shaft runs on a large-diameter roller bearing at the front, and is supported by the

gearbox input bearing at the rear. An automatic grease lubrication system ensures that the bearing is kept clean and lubricated between services.

DYNAMIC SEAL

The turbine utilises a multiple-lip seal on the low speed shaft to keep seawater out of the turbine. The seal unit is derived from proven ship's propeller shaft seals, and is actively grease lubricated to preserve its life and exclude water. It contains sensors to alert the operator of any leakage or deterioration so that corrective action can be taken.



Scada and Condition Monitoring

NACELLE MAIN BODY

The nacelle main body is a steel fabrication that supports the driveline, translating all loads down towards the foundation, and provides a dry housing for the key and ancillary equipment. When onshore, the inside of the nacelle can be accessed through a single hatchway for maintenance.

The turbine is designed for high quality and easy of manufacture. Components are pre assembled and acceptance tested into core modules, most of which are assembled to the nacelle main body. All flange joints between the core modules and the nacelle main body have double static seals, for redundancy and so that the joints can be easily vacuum pressure tested to ensure the finished product is water tight, prior to turbine deployment.

YAW DRIVE

The turbine always operates facing the oncoming current. A yaw system is required to ensure realignment to the changing tide; approximately every six hours. Tidal currents are generally in a consistent direction during a single ebb or flood tide, so the yaw can be fixed when the turbine is generating, and the yaw system only needs to be activated at slack water, between tides. The AR1500 has a novel yaw locking mechanism which makes for a compact, simple design.

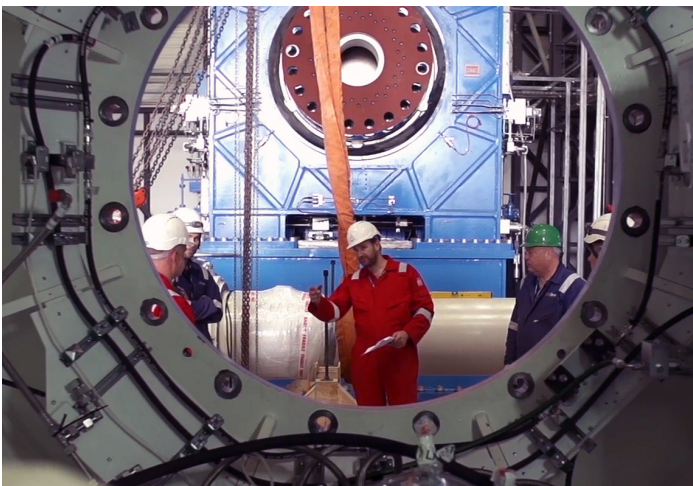
STAB & CONNECTION MANAGEMENT SYSTEM (CMS)

The turbine is connected to its support structure via a gravity stab mechanism. This comes in two halves, with the male on the turbine and the female on the support structure tower. The turbine is lowered onto the structure by a DP vessel, without any need for divers or ROVs. The stab is designed to progressively align the turbine with the support structure as the two parts are brought together. Once mated, the turbine is held in place by gravity, not requiring any locking mechanism.

The Connection Management System (CMS), uses wet-mate connectors, proven in the oil and gas industry to join the turbine's electrical and control systems to the subsea cable back to shore. This happens passively as the two halves of the stab come together, with the stab controlling the alignment and rate of descent of the turbine to ensure a smooth, repeatable connection. The connectivity from the shore to the turbine can be tested before the DP vessel releases the turbine to ensure everything is ready for operation.

SUPPORT STRUCTURE & LOWER CMS

The turbine can be fitted to a variety of foundations: gravity base, mono pile or pinned structures. The choice of foundation depends on



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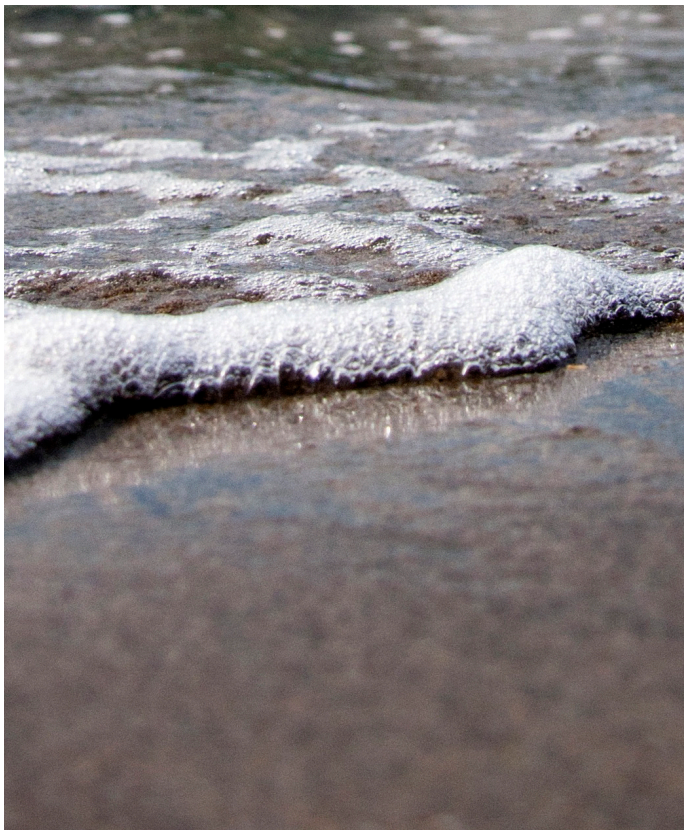


site-specific factors. The lower part of the CMS and the subsea cable are fitted to the support structure after it is installed, as a separate operation. Though the lower CMS is designed to last for the life of the turbine without maintenance, having it removable means that problems with it or with the subsea cable can be rectified without having to remove the whole support structure.

CONTROL SYSTEM, SCADA & CONDITION MONITORING

The turbine is controlled by an onshore PLC (programmable logic controller), which communicates with the turbine through fibre optics in the subsea cable. The turbine has an independent safety circuit within it that shuts the turbine down in the event of a malfunction, and protects the system from damage. The system has extensive diagnostic capabilities, and all trips can be reset from shore.

A SCADA system provides remote internet access to one turbine or an array of turbines, and collects operating data. The turbine has a comprehensive condition monitoring system that uses a wide variety of sensors and inputs to detect changes within the turbine and to warn of potential maintenance needs.



Tidal energy is predictable as tidal currents can be accurately forecast years in advance

SPECIFICATIONS - AR1500 HIGH FLOW

Operational Data

Rated Operational	3.0 m/s
Maximum Operational	5.0 m/s

Dimensions

Turbine Length	12 m
Weight in air	150T

Rotor

Blade Diameter	18 m
Hub Diameter	2.4 m
Pitch-able blades	Yes

Generator

Type	Radial flux PMG
Rating	1500 kW
Voltage	4.16 kV
Efficiency	97%

Gearbox

Type	Two-Stage Planetary Flexi-Pin
Rating	1500 kW @ 14 rpm
Ratio	1:27
Cooling	Passive (sea water)

Power Conversion

Type	Four Quadrant MV Converter
Rating	1500 kW

Brakes

Type	Fail-safe, stored energy released
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Stab & Foundation

Yaw Drive System	Yes
Foundation Type	Gravity-Based or Pylon



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