

ANDRITZ HYDRO Hammerfest

Renewable energy from tidal currents



ANDRITZ HYDRO

One of the world leaders in the hydropower business



ANDRITZ is a global and stock exchange-listed technology Group with more than 17,000 employees and over 180 production sites, service, and sales companies all around the world.

Today's ANDRITZ GROUP headquarter is located in Graz, Austria. With its business areas, HYDRO, PULP & PAPER, SEPARATION, METALS, FEED & BIOFUEL, ANDRITZ is one of the leading global suppliers of plants, equipment, and services to the markets it serves.

In a world which is striving to reduce the emissions of greenhouse gases and pollution, ANDRITZ HYDRO supports the customers in their environmental efforts by providing secure and sustainable technologies that maximize energy generation from hydropower and tidal power. Hydropower represents within this scenario the most important renewable resource of energy by far, while tidal power, with its worldwide availability can be considered as one of the most promising future energy sources with an estimated global potential of more than 150 TWh.

ANDRITZ HYDRO is one of the worldwide leading suppliers of electromechanical equipment and services 'From water to wire', capable of providing global solutions for tidal power arrays and hydropower plants, including all services related to the refurbishment and overhaul of existing facilities.

ANDRITZ HYDRO Hammerfest represents within the group the leading technology provider in the tidal power business.

One of the main goals is to provide innovative technologies and solutions to maximize the return on investment for the customers. This includes constant improvement of the energy efficiency of proposed equipment and technologies through a continuous Research & Development approach.

ANDRITZ HYDRO Hammerfest was established in 1997 in Hammerfest, Norway. The UK office was opened in Glasgow in 2008 in order to serve the promising local market potential including Ireland.

Based on a 300 kW tidal turbine, tested in Norwegian waters, a 1,000 kW tidal device was developed and tested at EMEC site (European Marine Energy Centre) before becoming part of the world's first tidal array, planned for installation in Scottish waters in 2013.

A global structure, the commitment to serve our customers locally all around the world, and proven experience and technologies are only some of the reasons why our customers can be assured of obtaining the best energy-related applications from us.

Highlights

- More than 170 years of experience in the manufacturing of electromechanical equipment
- More than 120 years of experience in electrical equipment
- Over 30,000 turbines installed, totaling more than 400,000 MW
- Complete power plant range up to 800 MW
- Leader in service and rehabilitation
- First grid-connected tidal turbine worldwide

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Renewable energy from tidal currents

ANDRITZ HYDRO Hammerfest develops the most energy-efficient, modular tidal turbine solutions capable of harnessing the energy in tidal currents, building on 15 years of knowledge and experience in hydropower, wind energy, as well as offshore oil and gas industry.

Since its beginning, the company has been a frontrunner in the design and installation of tidal turbines and was the first in the world to successfully generate electricity from tidal currents and deliver power to the electrical grid.

ANDRITZ HYDRO Hammerfest strives to be the leader in the development of technologies capable of providing full turnkey solutions to customers by harnessing the high energies and predictable power potential of tidal streams.

ANDRITZ HYDRO Hammerfest's modular tidal technology solutions are designed to allow optimal integration in the daily operation plans of the customers, supporting the worldwide energy mix and delivering environmental benefits.

Highlights

- Clean and renewable energy
- Low environmental impact
- Modular equipment design
- High predictability of energy generation
- First grid-connected device



Tidal Energy

Predictable and reliable

Tidal forces are a result of periodic variations in the gravitational attraction exerted by both the sun and moon together with the centrifugal forces associated with the rotation of the earth. These forces create corresponding motions or currents in the world's oceans with a period between high tide and low tide of 12 hours and 25 minutes.

Additionally, a relationship between the sun and the moon causes a variation in maximum and minimum tide heights over a period of 14 days.

Tidal characteristics are mainly influenced by bathymetric conditions, coastline morphology and current directions. In some specific regions, high tidal ranges can result in strong currents, which are the basis for the ANDRITZ HYDRO Hammerfest technology, allowing highly predictable and reliable energy generation.

The forces produced by the tides can be basically used to generate electricity in two different ways:

Potential energy

Energy from a water head is called potential energy. By using pressure turbines, this energy can be converted into electrical power.

Typical examples are tidal barrages, which make use of the potential energy available from the difference in head between high and low tides. Barrages are basically dams across the full width of a tidal estuary. They harness this potential energy by means of hydropower turbines.

Kinetic energy

The kinetic energy of moving water can be converted into electrical power by using tidal turbines. This form of energy yield is the basis of our technology.

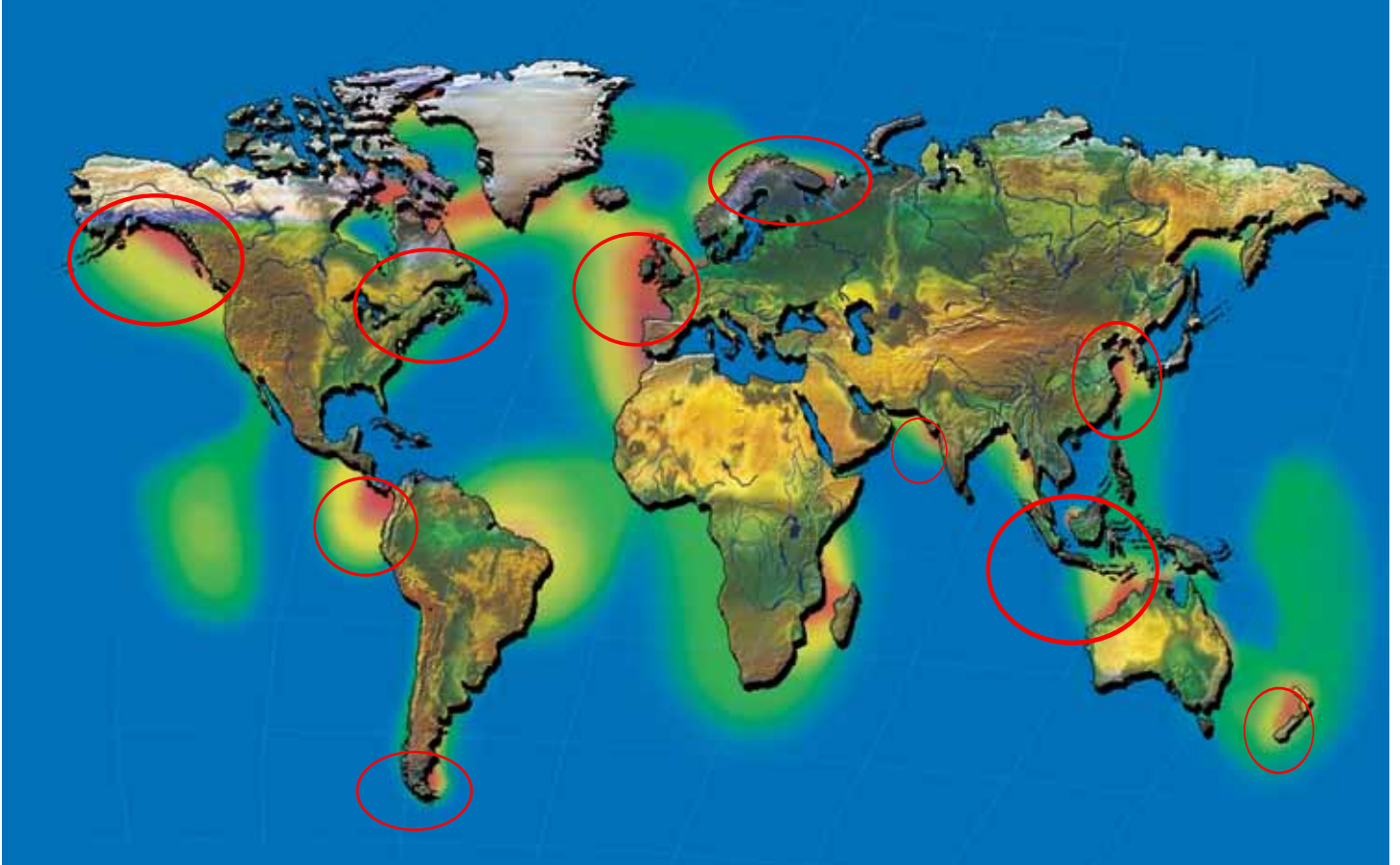
The turbines are placed in areas with high tidal movements, and are designed to capture the kinetic motion of the ebbing and surging of ocean tides producing strong bi-directional currents that can be converted into electrical power. Unlike barrage-type systems, this technology does not require the construction of a barrier across a waterway, and hence does not have any of the adverse environmental effects associated with such developments.

ANDRITZ HYDRO Hammerfest exploits kinetic energy in tidal waters



Global market

A broad range of potential sites worldwide



Tidal current electricity is clean, renewable, reliable and predictable. While ocean currents move slowly relative to typical wind speeds, they carry a great deal of energy. Sea water has more than 800 times the density than air, so for the same rotor swept area, water moving at 2.5 m/s (5 knots) exerts about the same amount of force as a constant 350 km/h wind.

Ocean currents thus contain an enormous amount of energy that can be captured and converted into a usable form.

In addition, as oceans cover more than 70% of earth's surface, ocean energy represents a vast source of energy, estimated to have some 150 TWh per year of economically exploitable resource available worldwide.

Despite these promising numbers, many potential sites are not being explored currently, although global tidal power production is expected to grow continuously as the technology develops.

Furthermore, governments have recognized the great potential of ocean energy and have begun significant incentive programmes to harness it. In several countries worldwide marine energy is currently one of the technologies receiving the highest level of subsidies per MWh of energy generation.

Tidal turbines

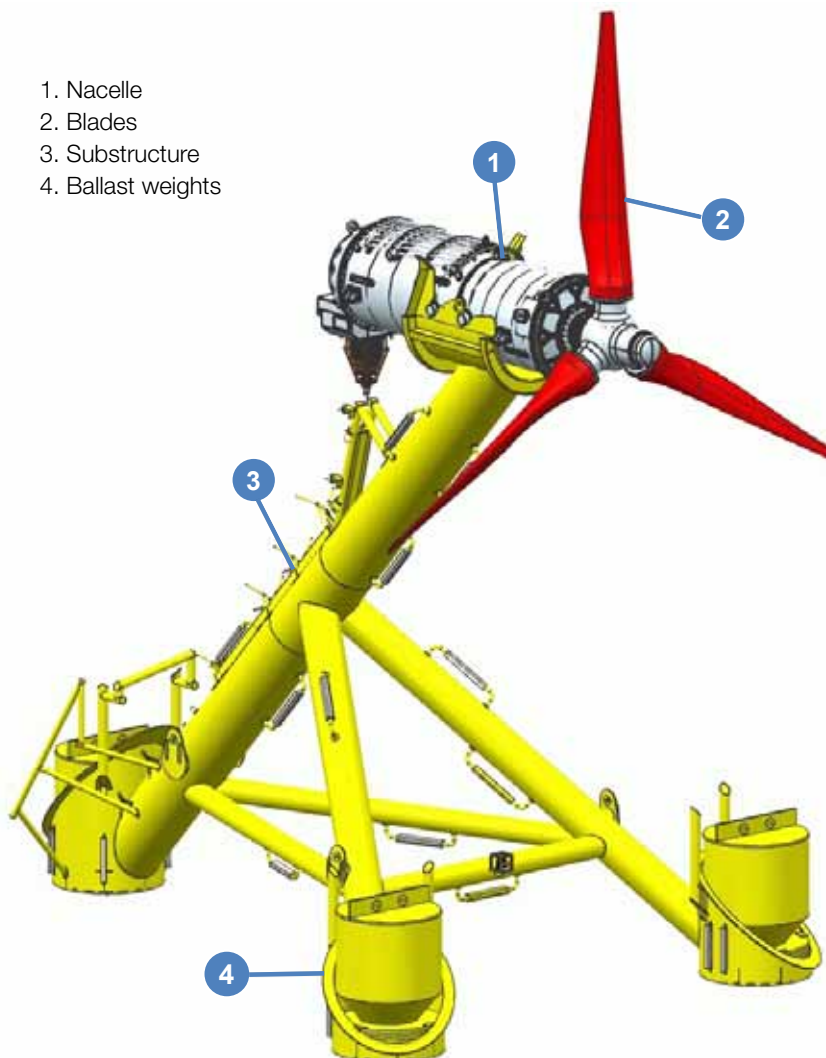
Modular product range

Tidal turbines are best described as underwater wind mills, but with shorter blades rotating at slower speed. The rated output of the devices depends on the water current conditions at a selected site. For maximum energy yield from the available resources the turbines can be easily combined in arrays consisting of several units.

Designed for water depths of between 35 and 100 m, the tidal turbines are deployed on the seabed and kept in position by gravity, pins or pilings (depending on the seabed and tidal stream characteristics). This eliminates any visual or audible impact above the surface and, in addition, normal shipping traffic will not be affected by the presence of the tidal arrays. The horizontal axis turbines are equipped with a specially-designed pitching system allowing optimal harnessing of tidal currents in both ebb and flood directions. The whole substructure is designed to have a small footprint while the nacelle is optimized to minimize the wake effect caused by the water flows. Unique marine installation methodologies have been developed to minimize installation times and to exclude the use of divers, requiring only the support of Remotely Operated Vehicles (ROV) for monitoring purposes.

ANDRITZ HYDRO Hammerfest tidal turbines are designed to generate power from water currents with a speed of 1 m/s or more.

1. Nacelle
2. Blades
3. Substructure
4. Ballast weights



Main features

- Proven technology solutions
- Proven track record of power delivery to the grid
- Suitable for use in coastal waters
- Suitable across a range of water depths and velocities
- Reliable operation and maintenance
- Simplicity of installation and maintenance
- Optimized turbine control and energy yield by variable-speed blade pitching mechanism and nacelle yawing system

Technical characteristics

Rated power:	500-2,000 kW (site dependant)
Power regulation:	Variable pitch, yawing system, variable speed
Operating depth:	35-100 m
Rotor:	
Type:	3 bladed open
Rotor swept area:	300-500 m ²
Nominal speed:	approx. 10 rpm
Generator:	
Type:	Induction
Nominal output:	500-2,000 kW
Weight:	
Nacelle:	approx. 130 t
Substructure:	approx. 150 t
Installation:	Heavy lift vessel/barge (with ROV support)
Lifetime/Service:	25 years/every 5 years

References

EMEC, United Kingdom

First pre-commercial tidal turbine installed at EMEC (European Marine Energy Centre).

Type:	HS1000
Installation:	December 2011
Grid connection:	February 2012
Site:	Fall of Warness, Orkney, UK
Rated power:	1,000 kW
Water depth:	52 m
Rotor diameter:	21 m



Kvalsund, Norway

World's first tidal turbine prototype connected to the grid.

Type:	HS300
Installation:	2003
Grid connection:	2004
Re-installation:	2009 (after maintenance)
Site:	Kvalsund Finnmark, NO
Rated power:	300 kW
Water depth:	50 m
Rotor diameter:	20 m
Total operating hours:	>16,000 h



From feasibility to operation

Four phases to a successful project



Feasibility assessment

To consider the unique morphology of each possible location a detailed site assessment is required. Important parameters are water depth, current velocity, bathymetry, profile and flow directions, wave and turbulence impact, grid connection, and environmental aspects.

Assessments are undertaken between the customer, ANDRITZ HYDRO Hammerfest and any required third party, defining the basic parameters for the future project including, for example, layout and cost evaluation.



Engineering and pre-design

The ANDRITZ HYDRO Hammerfest team consists of highly qualified and experienced engineers and project developers, working in close cooperation to develop the best 'value-for-money' array layout for each specific sites. Well-proven project management methodologies combined with a project-

oriented approach are the basis for optimal tidal power solutions. By leading the entire project management process, ANDRITZ HYDRO Hammerfest is capable of applying all of the required knowledge, skills, tools and techniques to meet customers' expectations.



Project execution and implementation

In the continuous quest to achieve customer satisfaction, the quality of service provided is equally as important as the quality of the product. Therefore a global presence and the cooperation with strong partners enable ANDRITZ HYDRO Hammerfest to provide

professional solutions that ultimately satisfy every requirement of the customer.

Systematic project management guarantees the fulfilment of quality, cost and timeline requirements.



Service and maintenance

ANDRITZ HYDRO Hammerfest offers comprehensive and tailor-made service and maintenance programs for its products. The turbines incorporate a condition monitoring system to provide a predictive maintenance capability. This avoids costly unplanned repair activities and potentially extend the planned maintenance intervals beyond that predicted.

ANDRITZ HYDRO Hammerfest's global structure and organisation, as well as international partnerships enable to undertake service and maintenance activities in close proximity to the sites, minimizing not only the potential downtime periods, but also associated costs.

Installation capabilities

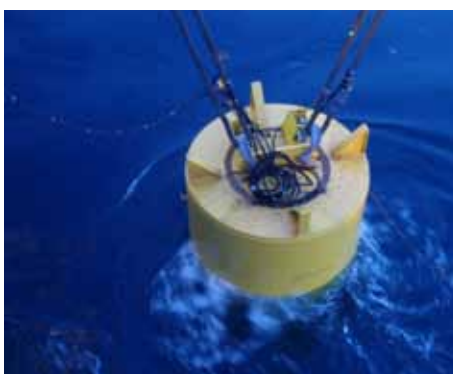
The installation concept and philosophy of ANDRITZ HYDRO Hammerfest allows the deployment of the turbines under the most severe weather conditions down to depth of 100 m, across the different site morphologies found worldwide.

Installation is generally achieved in three phases:

- Installation of the substructure followed directly by ballast weights or pinning/piling
- Connection of the subsea cable to the turbine to establish the electrical connection to the on-shore substation
- Deployment and lowering of the nacelle (with mounted rotor blades) onto the substructure.

Installation is diverless with only the support of standard ROVs. Moored barges or heavy lift DP vessels (Dynamic Positioned) are required depending on the site and weather conditions.

For maintenance only the nacelle has to be retrieved.



Research & Development

ANDRITZ HYDRO Hammerfest's Research & Development (R&D) activities started in the 1990s, when the HS300 turbine was developed, manufactured and, in 2003, installed in Kvalsund, Northern-Norway, as world's first grid-connected tidal current turbine.

Based on the tested technology, full-scale turbines, with a rated capacity of between 500 kW and 2,000 kW, were designed for the planned commercial applications. The first 1,000 kW turbine was successfully installed at the European Marine Energy Cen-

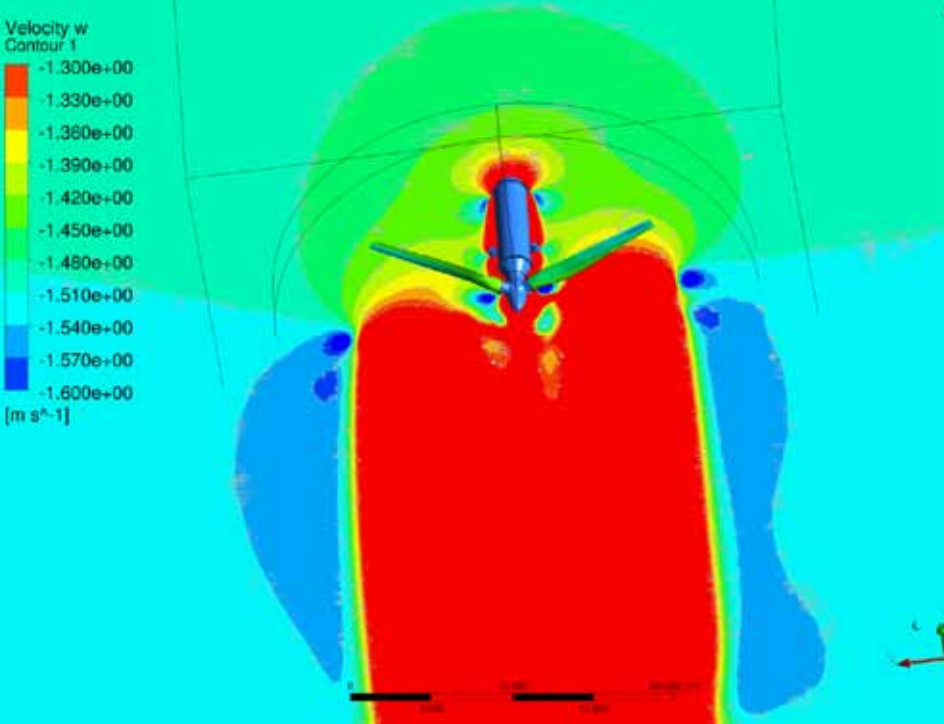
tre (EMEC) in Orkney, UK, in December 2011, considered to be one of the roughest marine sites in the world.

ANDRITZ HYDRO Hammerfest efforts in R&D keeps the company at the front line of innovation, able to offer the best solutions to the customers, from both a technical and commercial point of view.

The highest quality standards, latest technology and competitiveness — values which are incorporated into every phase of our activities — are fundamental require-

ments for the delivery of the next generation of tidal arrays.

Research findings from field tests, model test in laboratories, numerical flow simulations, and technology innovations are all combined into an optimized overall solution. It is this comprehensive approach to product innovations which keeps ANDRITZ HYDRO Hammerfest on the forefront of technology.



In harmony with nature



The high efficiency of the turbines supplied by ANDRITZ HYDRO Hammerfest results in careful management and protection of the environment and natural resources.

Environmental sustainability and awareness have become more and more important in the global market. In line with this philosophy, ANDRITZ HYDRO Hammerfest's mission is to implement the latest technologies achieving the highest possible efficiency while maintaining the balance of environmental and natural resources.

This focus on the environment has been implemented throughout all the steps of the project and its technological developments.

Therefore, since 2001 a series of comprehensive Environmental Impact Assessments (EIA) have been undertaken, starting before the HS300 unit was installed.

The EIA consider the potential impact that tidal turbines could have on business activities, outdoor life, marine life, and seabirds. Among other assessments, noise measurements have, for example, been undertaken at previous projects.

To date, these EIA have concluded that there is no significant impact on the areas studied.



