IHI Demonstrated the World's Largest Ocean Current Turbine for the First Time in the World

Floating type ocean current turbine 100 kW-class demonstration system "Kairyu"

Ocean current power generation is a harvesting method of ocean renewable energy. This energy regeneration technology is intended to effectively utilize the Kuroshio Current and is suited to Japan. In August 2017, IHI and New Energy and Industrial Technology Development Organization (NEDO) conducted a demonstration experiment of the world's first 100 kW-class ocean current turbine located off the coast of Kuchinoshima Island, Kagoshima Prefecture and obtained data for commercialization.

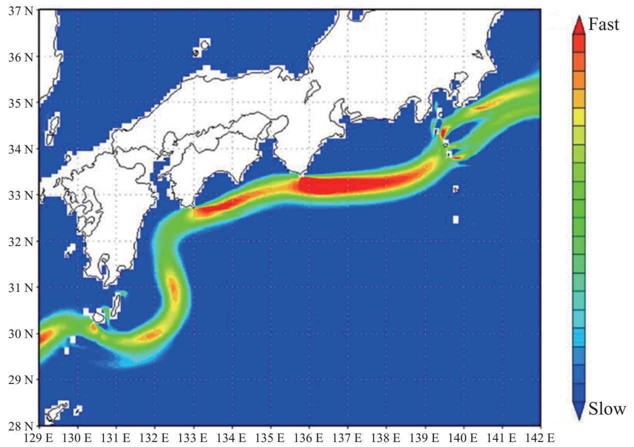
"Kairyu" — 100 kW-class floating type ocean current turbine for demonstration

Effective utilization of the enormous amount of energy being held unexplored in the sea

In the field of energy regeneration, photovoltaic power generation and wind-power generation are becoming widespread. Meanwhile, Japan, having the world's sixth largest territorial waters and an exclusive economic zone, needs ocean renewable energy to be realized.

A variety of approaches to the realization of ocean renewable energy have been proposed. Approaches include ocean current power generation, which uses a big ocean current in the open sea, such as the Kuroshio, to rotate turbine rotors; tidal flow power generation, which uses tidal flow in a strait or the like to rotate turbine rotors; wave-activated power generation, which uses the vertical motion of waves; ocean thermal energy conversion, which uses the temperature difference between surface and bottom; tidal (level difference) power generation; and seawater concentration difference power generation.

In Europe, the development of tidal flow power generation has been making progress and reached the commercialization phase. Meanwhile, Japan is located near the Kuroshio, one of the world's most powerful ocean currents, and one estimate states that if the energy present in the Kuroshio could be harnessed, it would amount to approximately 205 GW, which is comparable to Japan's total electric power generation. In addition, whereas the capacity factors of many types of energy regeneration, such as photovoltaic power generation, wind-power generation, and tidal flow power generation,



Example of analysis of the distribution of the Kuroshio

range from 10 to 40%, the capacity factor of ocean current power generation is estimated to be at no less than 40 - 70% levels, meaning that ocean current power generation could be a base power source that ensures stable power generation. Moreover, in the Kuroshio, which can be up to 100 km across, it would also be possible to install a number of ocean current generators to create a large-scale power generation farm. Ocean current turbines are thought to be of great promise as a source of future renewable energy in Japan. Since 2011, IHI and NEDO have been jointly developing an ocean current turbine based on a unique concept.

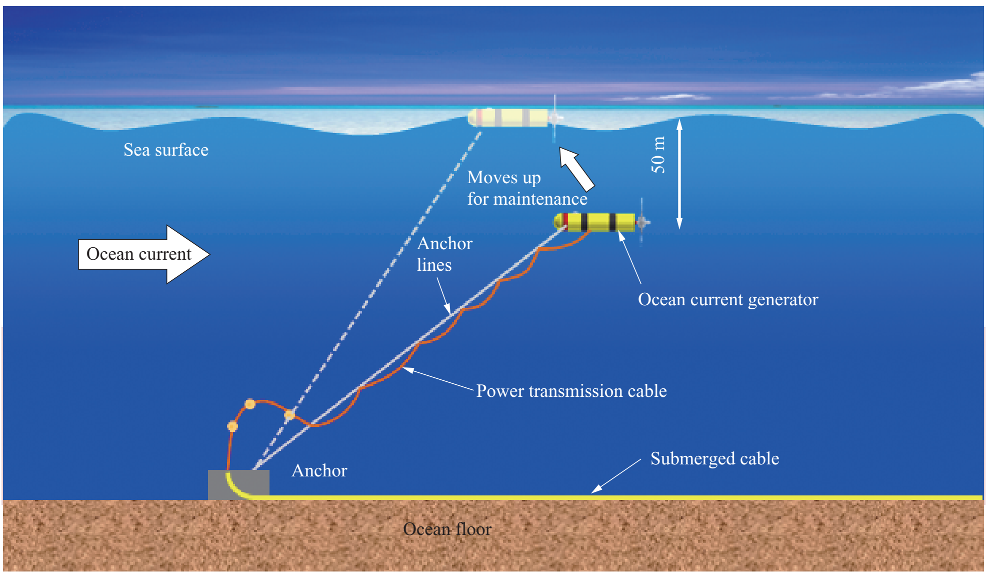
World's first floating type ocean current turbine
100 kW-class demonstration system "Kairyu"

The mean flow speed of the Kuroshio is said to be 1 - 2 m/s (approximately 2 - 4 knots). Its flow speed varies depending on the water depth; in other words, water near the sea surface flows faster. Given this, an ocean current generator, installed near the sea surface, will be capable of generating power more efficiently. Nevertheless, waves caused by a typhoon might have a height of 20 m or more, and a higher level of safety is therefore required to install an ocean current generator near the sea surface. In consideration of this issue, we adopted the floating type ocean current generator, which is moored at a depth of around 50 m below sea level. The floating generator anchored to the bottom of the sea takes advantage of the balance between its buoyancy and the drag caused by the ocean current, thereby generating electric power while floating at any desired depth. In addition, two turbine rotors, left and right, are rotated in opposite directions to each other to cancel rotary torques associated with the rotation of the turbine rotors, thereby stably maintaining its position under water. When undergoing maintenance work, the ocean current generator can move up to the sea surface, enabling operations and the like to be easily performed on the sea.

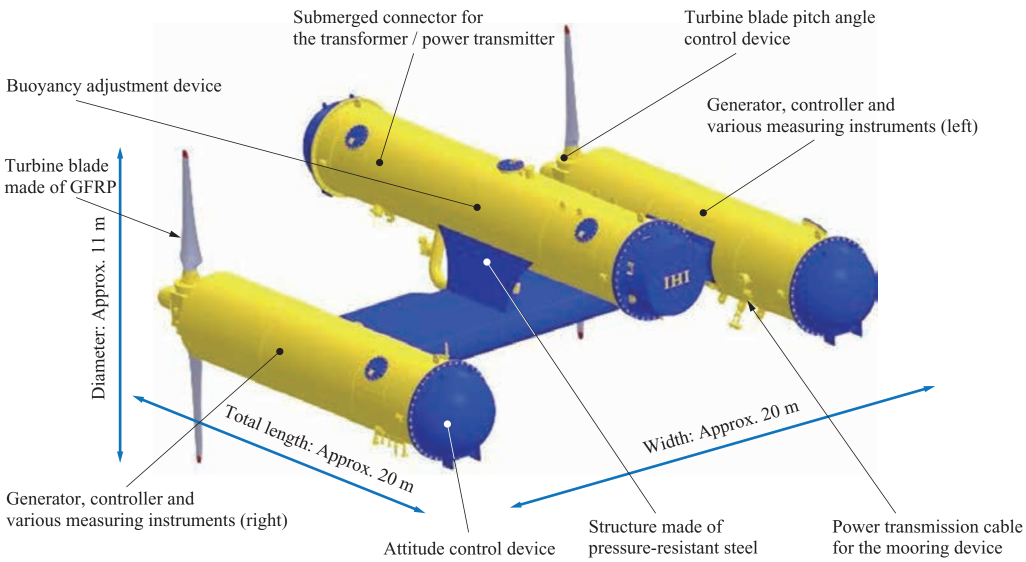
In order to verify the validity of the concept of this type of floating power generation in the actual Kuroshio, we developed an ocean current generator for demonstration called Kairyu. It comprises a combination of three cylindrical floats called pods, having a total length of approximately 20 m, a width of approximately 20 m, and a turbine rotor diameter of approximately 11 m. In addition, the rated flow speed is 1.5 m/s (approximately 3 knots) and the rated output, i.e., generating capacity is approximately 100 kW (50 kW × 2 units).

Kairyu includes various ingenuities for it to stably generate power under water.

It is designed to operate around 50 m below sea level to generate power efficiently, having a mechanism that utilizes depth measurements from water pressure sensors and a buoyancy adjustment device built into the central pod to



Conceptual diagram of the floating type ocean current turbine



Overview of Kairyu (100 kW-class demonstration system)

enable the optimum position under water to be maintained.

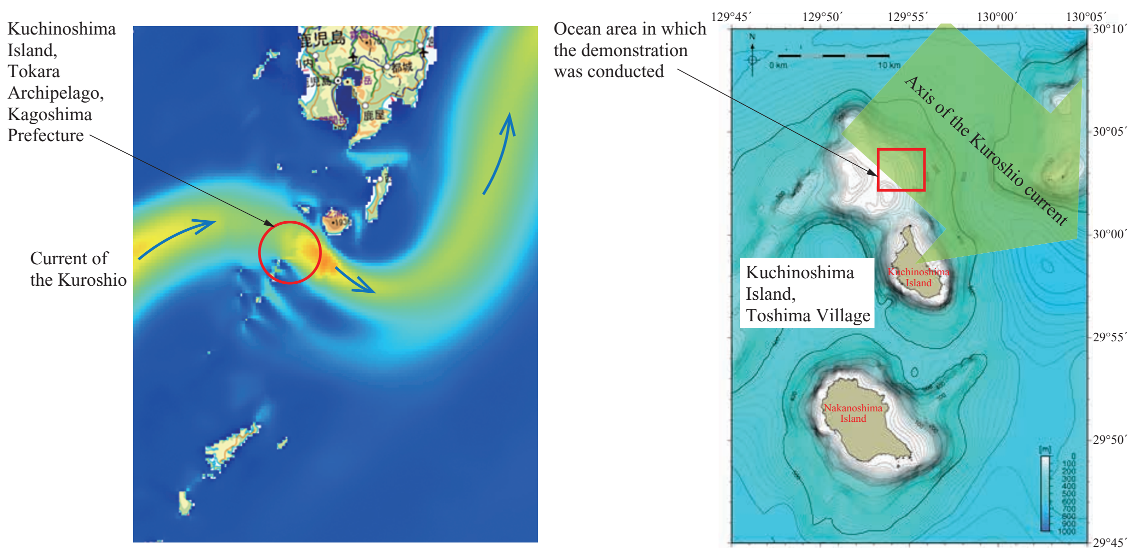
Moreover, attitude control devices are built into the ends of the left and right pods to enable the ocean current generator to generate power while floating with the proper attitude in the ocean current. In addition, the ocean power generator has a mechanism that changes the pitch angle of the blades of the turbine rotors in accordance with the speed of the ocean current so that electric power can always be efficiently generated at any flow speed. Usually, this control is autonomously performed by the control system included in the floats.

Technologies for ensuring the watertightness and resistance to water pressure of floating structures and rotary machinery are important for enabling such a generator to operate under water. In the development of these technologies, IHI's shipbuilding technologies were put to full use.

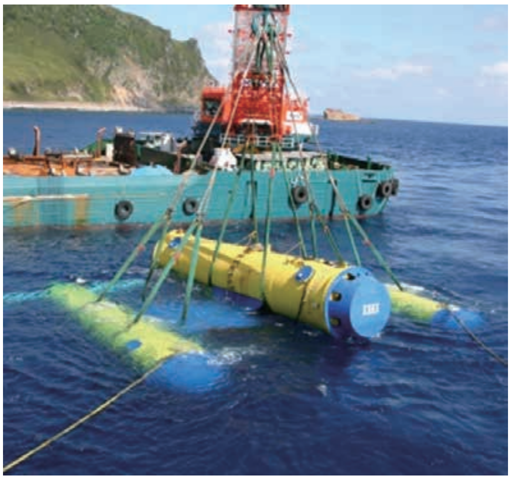
Success in the demonstration experiment conducted off the coast of the Kuchinoshima Island, Kagoshima Prefecture

Kairyu was completed in July, 2017, and an open sea power generation demonstration was conducted in the Kuroshio off the coast of Kuchinoshima Island (Toshima Village, Kagoshima Prefecture) in August, 2017. In the demonstration experiment, we validated the floating type ocean current turbine in terms of workability and the power-generating performance and attitude control in the actual Kuroshio environment.

Prior to the demonstration experiment, we conducted a towing test in the Koshiki Straits off the coast of Noma Misaki Cape (Minamisatsuma City, Kagoshima Prefecture) with the objective of verifying the power-generating



Site of the demonstration experiment (source: NEDO ocean energy portal site)



Preparations for the demonstration experiment at the site off the coast of Kuchinoshima Island

Installation of Kairyu at the site off the coast of Kuchinoshima Island

performance and underwater behavior of the ocean current turbine. In this towing test, Kairyu was towed to simulate a water current similar to the Kuroshio, and in this water current, electric power was generated. In this test, power generation with a rated output of 100 kW was achieved at a rated flow speed of 1.5 m/s.

Following the towing test, the aforementioned demonstration experiment was conducted, with a 280 t anchor at the bottom (at 100 m below sea level) of the test sea area and with Kairyu anchored to it with anchor lines made of High Molecular Polyethylene (HMPE) rope.

The demonstration experiment was conducted for seven days. In this demonstration, we conducted validations of the autonomous control system, the power-generating performance of Kairyu, the stability of the floats, and so forth. During the experiment, the Kuroshio had a flow speed of approximately 1.0 m/s, and we confirmed that up to 30 kW of electric power was generated from that ocean current.

In this demonstration experiment, we used a work barge anchored in waters approximately 1.5 km away from Kairyu to act as land and performed various operations, including the remote operation and monitoring of Kairyu, as well as receiving the generated electric power, and then successfully confirmed their validity.

Furthermore, we were able to complete the installation and removal works in the Kuroshio safely and on schedule, taking advantage of the floating type system and the simple techniques for installing it.

This demonstration experiment showed that Kairyu exhibited performance as designed and that floating type ocean current turbines would be able to operate and generate power in the actual Kuroshio, enabling us to accumulate a large quantity of valuable data and know-how toward their commercialization in the future.

Toward long-term reliability testing

The scale-up of power generation effectively reduces power generation costs, though this does not only apply to ocean current generators. We will continue to develop the ocean current turbine with the aim of realizing an ocean current power generation farm equipped with a full-scale production turbine with a rated output of 2 MW (1 MW × 2 units) and a turbine rotor blade diameter of approximately 40 m. For this purpose, we need to take further steps toward the verification of long-term reliability and safety of floating type ocean current turbines.

We also need to carry out detailed studies and research on the characteristics of an ocean current, which are not known fully at present.

It could be said that the present demonstration experiment widely opened the door for the realization of ocean current power generation. As an approach to the commercialization of this technology, a floating type ocean current turbine capable of stably generating power is highly expected to serve as a low-cost energy source for remote islands, where power generation is forced to rely on internal-combustion power generators because it is difficult to receive electric power from the main islands of Japan via power cables.

IHI is committed to the research and development of new energies with the objective of responding to social environment changes, preventing global warming, and reducing greenhouse effect gases toward the realization of a sustainable low-carbon society.

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