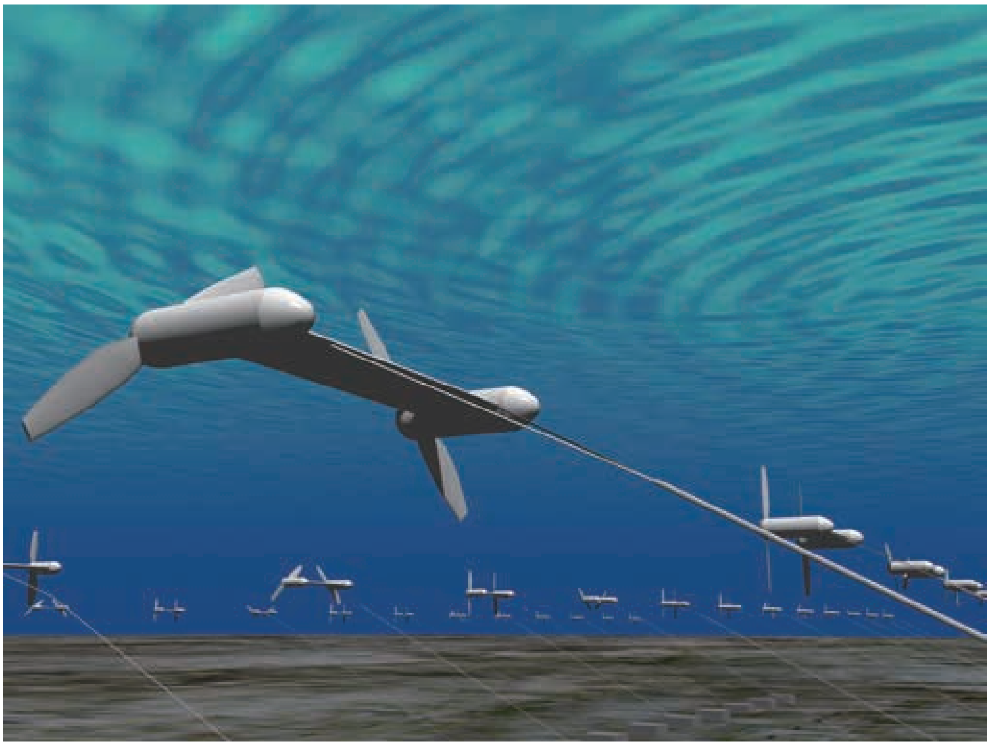
Power Generation Using the Kuroshio Current

Development of floating type ocean current turbine system

Ocean currents, such as the Kuroshio Current, are expected to be effectively used as marine renewable energy in order to supply sustainable energy and reduce greenhouse gas emissions. IHI is aiming to realize power generation using an ocean current and is working toward development of a floating type ocean current turbine system.



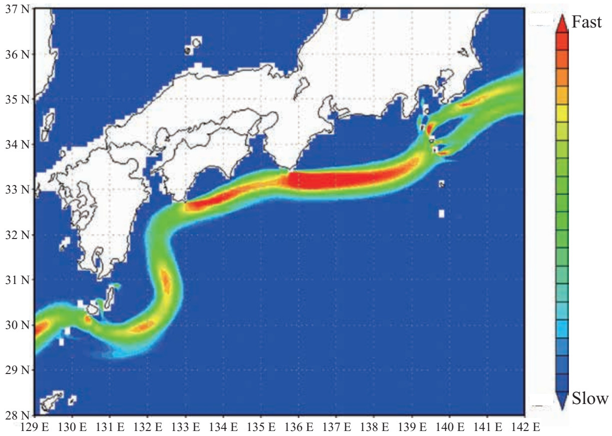
Floating type ocean current turbine system

Japan's Exclusive Economic Zone (EEZ) extending outside Japanese territorial waters is the world's sixth largest EEZ. Development of marine renewable energy in the EEZ needs to be actively promoted from the viewpoints of reduction in greenhouse gas emissions and energy security. As seen in the map on the next page, the ocean current known as the Kuroshio Current flows near the coastal areas of Japan stably throughout the year. Accordingly, it is expected that use of its enormous energy will allow us to establish a new clean and stable source of electricity based on Japan's own natural energy.

In order to realize power generation by using this ocean current, IHI is developing a floating type ocean current turbine system. In this article, we introduce its technological characteristics.

Outline of floating type ocean current turbine system

We are working toward the development of a floating type ocean current turbine system in the framework of a joint research consortium formed with Toshiba Corporation, the Graduate School of Frontier Sciences of the University of Tokyo, and Mitsui Global Strategic Studies Institute. The consortium is commissioned to address "Research and Development of Natural Energy Technologies Including Wind Power, Research and Development of Ocean Energy Technologies, and Research and Development of Next-generation Ocean Energy Power Generation Technologies." The New Energy and Industrial Technology Development Organization (NEDO) publicly invited candidates to



Flow of the Kuroshio Current

participate in these topics for research and development, and the member organizations of the consortium were selected to achieve the project.

In order to effectively and economically use the energy of the ocean current, this project aims to develop the elemental technologies for realizing a floating type ocean current turbine system and put ocean current power generation into practical use in the future by performing evaluations, such as evaluation of its profitability. This system is excellent in the following characteristics.

(1) Ocean currents do not vary significantly in speed and direction at any time day or night all year round. This system will use this stable ocean current energy to continuously generate power at high capacity factor for a long time. Accordingly, it can be expected that the system will produce a large amount of electric power as a basic source of electricity.

(2) In this system, the floating turbines are moored to the seabed so that they remain suspended in the ocean. They can even be installed in deep water, which means that a wide ocean area is available for power generation using this system. Therefore, it allows us to construct a large-scale energy farm consisting of a number of power generators. Construction of such a large-scale energy farm is effective in reducing costs for power transmission to a land area relative to the total power transmitted.

Since the system will be installed in the ocean, it can be operated at a depth where there is stable water flow without being affected by waves and will not interfere with the navigation of ships. In addition, the system can be easily installed by simple mooring, which will contribute to cost reduction.

(3) Rotary torque generated by turbine rotation can be canceled by coupling two counter-rotating underwater turbines. This will allow the turbines to maintain a stable position under the sea to achieve efficient power generation.

(4) For maintenance, the system can be surfaced when necessary by controlling the orientation and buoyancy of the floating body. Accordingly, maintenance and repair work can be easily performed.

By using these features, we are aiming to achieve the target cost, which NEDO applied to R&D on Ocean Renewables, at 20 yen/kW·h as CoE (Cost of Electricity).

In the following, we describe the development of elemental technologies necessary for realizing this power generation system.

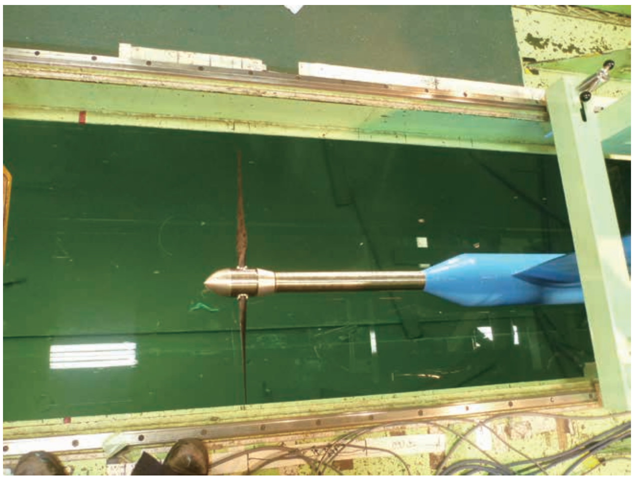
Development of turbine

In order to generate large electric power from an ocean current flowing at a relatively slow average speed of approximately 3 knots, it is necessary to develop an underwater turbine that will operate at high generation efficiency. This system will be constructed by using a horizontal axis turbine with a rated output of 1 MW, which is the same as a large wind power generator.

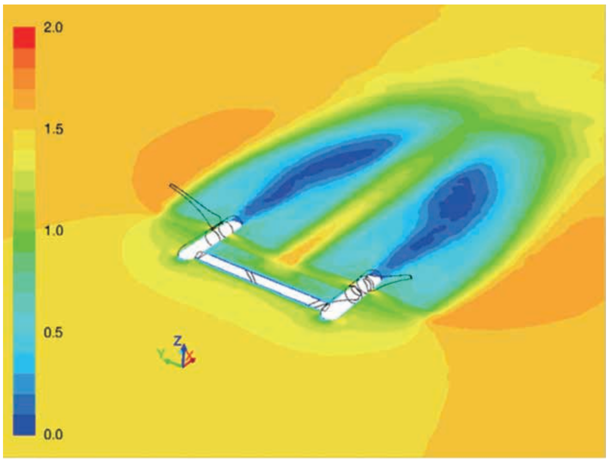
The underwater turbine needs to operate at high generation efficiency in various operation states ranging from a low current-speed state in which the turbine starts power generation to the maximum current-speed state. Accordingly, we examined its hydrodynamic performance, such as torque and reaction force generated by its turbine blades, by analysis based on Computational Fluid Dynamics (CFD) and tank experiments using model blades. The photograph below shows a performance test that was performed in an IHI towing tank using a set of 1/30-scale model turbine blades.

The hydrodynamic force acting on the turbine blades varies under the influence of inflow, such as the wake of the structures connecting two turbine generators and current speed distribution in the depth direction, while turbines are rotating. To estimate such variations, we conduct CFD analysis which simulates turbine rotation and evaluate the fluctuation of the hydrodynamic force acting on the turbine blades.

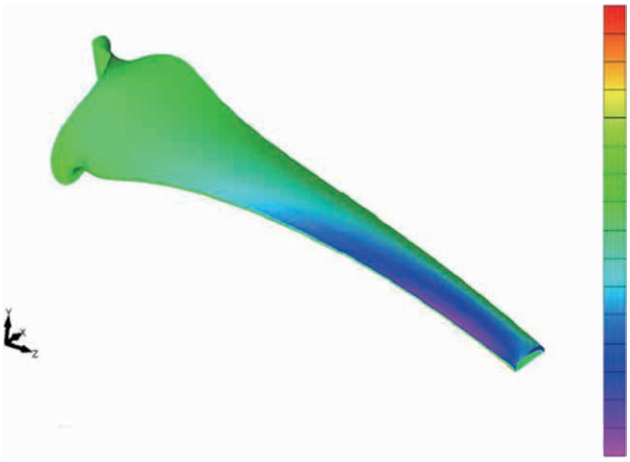
Since the diameter of the turbine may reach approximately 40 m, it is essential to accurately estimate the load exerted on



Turbine open test in towing tank



Example of CFD analysis for flow around rotating turbine


Example of pressure distribution on a turbine blade

the blades and to select a structure and a material that allow the blades to withstand the load. The above diagram shows an example of the analyzed distribution of pressure acting on turbine blades. On the basis of this distribution, we are conducting structure analysis using structural dimensions and materials as parameters to evaluate the deformation and stress of the blades. In addition, we are estimating the fluctuating loads and related fatigue strength to develop a high-reliability large blade structure by ensuring durability under seawater corrosion environments, and are aiming to establish technologies for a low-cost manufacturing process and design standards suitable for ocean current generation.

Development of floating body and mooring system

In the floating type ocean current turbine system, the turbine generator is connected to the end of a mooring rope anchored to the seabed. The system is operated with the turbine "flying" in the sea like a kite in the sky. This mooring method allows the turbine to be installed in deep-water areas in the open sea through which the Kuroshio Current is passing.

During operation, it undergoes state changes: floating on the sea surface, submerging into the sea, floating underwater to generate power, termination of power generation, and surfacing. Accordingly, safety needs to be ensured in a manner appropriate to each state. Therefore, it is essential to select the optimum arrangement and shapes of all the components with consideration given to the influence on the safety of the floating body. It is also very important to control the balance among forces acting on the system, such as thrust of the turbines, buoyancy, and the tensile force of the mooring rope.

We have conducted motion simulations of the floating body and corresponding tank experiments on models in

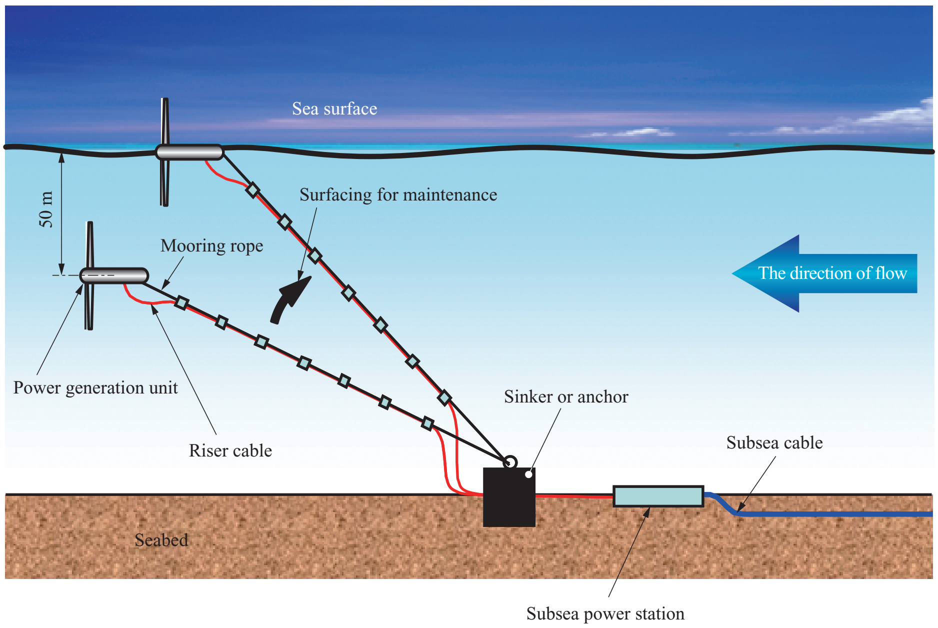
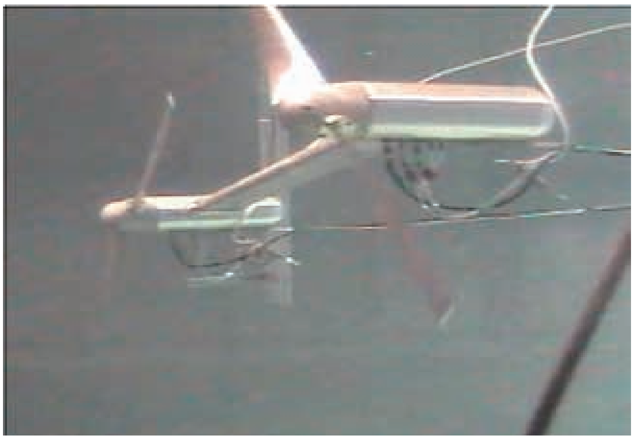
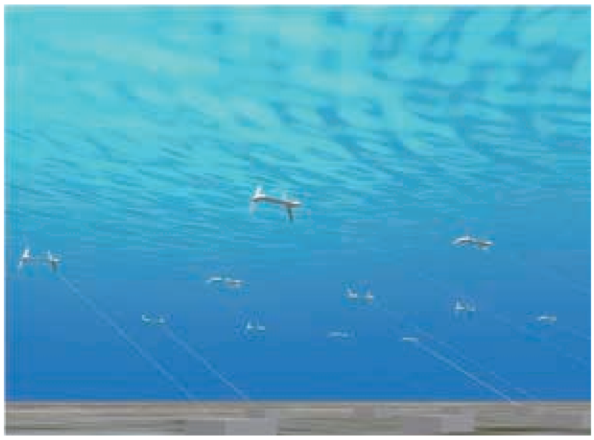


Diagram of floating type ocean current turbine system



Tank experiment using scale model of floating turbine



Large-scale energy farm

order to evaluate the influence of these factors on the floating motion. We are investigating the controllability required for ensuring attitude, depth, and position stability, not only under steady state conditions, but also when influenced by different-scale eddies passing near the system, as well as in emergencies for safety's sake.

In order to realize an appropriate system, it is also important to adequately select a structure resistant to pressure at various water depths, a high-strength mooring rope withstanding strong tensile forces, and an anchor embedded in the seabed.

Development of power generator

Since ocean currents flow slowly, the turbines for a floating type ocean current turbine system will rotate slower than large windmills. Accordingly, an electric generator suitable for the slow rotation needs to be developed. In this process, it is essential to develop an optimum generator from the viewpoints of cost reduction, generator efficiency, and weight and dimensions.

In addition, this system will be used as a power plant for long-term unmanned operation under the sea. Accordingly, we are developing technologies for achieving long-term maintenance-free operation and methods for evaluating the life-time of the insulation of devices for the transmission and transformation of electric energy. The areas in which this system will be installed are far from coastal areas and lie in the deep water of the Kuroshio Current. Therefore, we are also developing a system suitable for the transmission and transformation of electric energy in these areas.

Investigation of characteristics of ocean currents and evaluation of profitability

We are developing technologies for this system with consideration given to its feasibility as an ocean current power generation business since its early stages.

Since the profitability of ocean current power generation significantly depends on the characteristics of the flow of the ocean current, which serves as the energy source for the power generation, it is essential to understand the flow. To understand the characteristics of the flow, we have conducted actual measurements of the Kuroshio Current with the aid of various tools such as the numerical prediction of the ocean current and an Acoustic Doppler Current Profiler (ADCP) for an extended period of time. On the basis of this information, we estimate the amount of power generation and the stability of the floating turbine, and utilize the estimations to evaluate the profitability by determining the design specifications of the system and estimating the cost of power generation. We have concluded from our estimates that a floating type ocean current turbine system can sufficiently achieve the target unit price of power generation when used in the form of large-scale energy farms (above diagram), which allow them to deliver their performance.

Power generation by using the floating type ocean current turbine system is characterized by the following two aspects: ① It is a low-cost mooring system that does not depend on installation area; and ② As a new power generation technology, the floating type ocean current turbine system can assume the role of a main source of electricity by using ocean current energy that provides high capacity with the aid of high-efficiency underwater turbines. By 2015, we will develop the elemental technologies described in this article. Subsequently, we will conduct demonstration experiments of power generation by using demonstration equipment.

IHI will continue to conduct research and development of the floating type ocean current turbine system in order to achieve the production of renewable energy from the ocean to realize a society founded on sustainable energy.

Inquiries:
Mechanical Technology Department,
Products Development Center,
Corporate Research & Development
IHI Corporation
Phone: +81-45-759-2828
Website: www.ihi.co.jp/en/