NEDO offshore wind energy progress Edition Ⅱ

Offshore Wind Condition Observation System Proving Research

Offshore Wind Power Generation System Proving Research

Mega-Size Wind Power Development System Technology Research and Development

NEDO

New Energy and Industrial Technology Development Organization

Nacelle

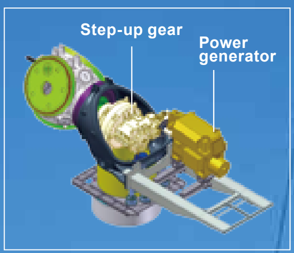
The container facility designed to store bearings, step-up gears, power generators and other components. Mounting with salt removal equipment and other features gives this unit greater effectiveness in salt-damage countermeasures than onshore facilities.

Power Generating System

☐ Step-up gear: System that raises blade rotations (by over a dozen round per minute) to 1,500~1,800 round per minute, for transmission to the power generator.

☐ Power generators: Induction generators simple in structure and low in cost and synchronous generators offering adjustments in voltage and other parameters, other types.

☐ Surveillance equipment: Use of remote surveillance systems to monitor offshore wind turbine operating status, structural fatigue and other conditions on real-time basis, exercising efficient maintenance.



Foundation

Structural portion used to support the subsurface tower.

☐ Gravity type: Foundation structure suitable when the ocean floor base is in a relatively favorable location. Interior is hollow, with slag serving as a weight injected to help stabilize.
(Offshore Choshi)

☐ Hybrid gravity type: Resistant to impact from the base, designed by adopting the advantages of the gravity system and jacket structure system.
(Offshore Kitakyushu City)

Offshore Wind Power Generation Project

Wind power generation involves lower power generation costs than solar, wave or tidal power. Among the various forms of renewable energy, wind power also compares favorable in terms of cost competitiveness. Within this genre, compared to onshore power generation, the advantages of offshore wind power include stable and efficient power generation and the ability to evolve to use of large-size wind turbines. As a result, the introduction and use of offshore wind power is rapidly advancing with the focus on Europe. In this issue, we focus in on projects aimed at realizing Japan's very first offshore wind power generation.
In these undertakings, NEDO is handling the oceangoing installation of offshore wind condition observation towers used to track offshore wind direction and velocity, and the wind turbines to be mobilized to actually generate offshore wind power.

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Japan First ! Rising to the Challenge of Offshore Wind Power Generation

With the key focus on Europe, construction of offshore wind power plants continues to pick up steam. Fueled by growing expectations for the role of renewable energy, interest in this sector is rising in Japan as well. NEDO has been advancing efforts in offshore wind power generation since 2009. In this feature, we profile the global trend toward offshore wind power generation, and the positioning of NEDO projects within this trend.

Masaharu Itoh, Senior Researcher, New Energy Department,
New Energy and Industrial Development Organization (NEDO)

View from the nacelle of Byobugaura (offshore Choshi in Chiba Prefecture), widely known as the “Straits of Dover of the Orient.”

Move from Onshore Wind Power Generation to Offshore Wind Power Generation

In the European Union (EU), there the introduction of wind power generation is being advanced at a greater rate than any other region in the world, member nations are assessed with legally binding numerical targets in the quest to achieve the goal of generating 20% of EU power with renewable energy by the year 2020. Within this trend, in view of high expectations attached to wind power generation, the decline in suitable onshore sites for such projects, interest in securing employment accompanying the fall in production at North Sea oil fields and other perspectives, moves are expanding to shift wind power generation from onshore to offshore locations.

Thus far, as of late 2012, 5400 MW of offshore wind power generation has been deployed, primarily in Europe. Offshore wind power generation is a promising option in Japan as well for expanding the deployment of wind power generation. NEDO initiated a feasibility study of offshore power generation in FY2008. In FY2009, a demonstration research project was launched with the construction of Japan’s first wind condition observation towers and offshore wind turbines for installation in the Pacific Ocean and Japan Sea to monitor the differing meteorological and oceanographic conditions. After repeated typhoons and strong waves, installation of the offshore wind turbine off the coast of Choshi, Chiba Prefecture, in the Pacific Ocean demonstration area was completed in October 2012. Likewise, installation of the offshore wind turbine off the coast of Kitakyushu City, Fukuoka Prefecture, in the Sea of Japan demonstration area was completed in March 2013. While being baptized in these severe natural environments, we were able to successfully guide the construction of Japan’s first offshore wind power generators to completion. This success was the result of the efforts of the project team members and the cooperation from the local areas. We would like to take this opportunity to express our heartfelt appreciation.

Three Challenges to Surmount

Among the available types of renewable energy, wind power generation offers the advantages of mature technological systems and a rich track record, as well as lower generation costs. For these reasons, the introduction and popularization of wind power is advancing.

In Japan as well, introduction of wind power generation has rapidly increased, primarily involving onshore installation, from the first half of the 2000s decade. At the end of fiscal 2011, total wind power output in Japan stood at approx. 2.55 GW (1,870 wind turbines). Looking to the future, however, forecasts are for a decline in suitable onshore locations for wind power generation due to wind conditions, restrictions on such sites and other impacting factors. In order to expand the implementation of wind power generation in spite of these conditions, the need exists to advance offshore wind power development – a sector believed to hold massive potential.

The challenges involved in offshore wind power development may be divided into three key categories.

The first is that of cost. Because offshore wind turbines are installed within ocean environments, the cost is said to run roughly twice that of onshore facilities. This includes the wind turbines themselves, the foundations (bases submerged in the waters), submarine cable installation work and other project aspects. In addition, the operation and maintenance (O&M; referring to parts replacement and other upkeep) work also differs from onshore wind turbines insofar as the demand for heavy expenditures. Costs likewise vary by distances from the shore, water depth and other elements. Because recent offshore wind farms in Europe are steadily moving further away from continental areas and into deeper waters, installation costs are also on the rise.

The second challenge category is technology. With early offshore wind turbines suffering frequent breakdowns in their step-up gears, generators, development of technology was advanced for means of raising reliability involving salt damage countermeasures and monitoring of wind turbine conditions. In addition, when moving installation locations from shallow to deeper waters, there is a need to increase per-turbine power generation in order to lower cost. This makes increased size and improved reliability a major theme in developing the technology for offshore wind turbines.

The third challenge concerns social acceptance. Clearly, offshore wind power generation will never be realized without the understanding of fisheries operators and other marine users. To earn their supports, environmental assessments are a must.

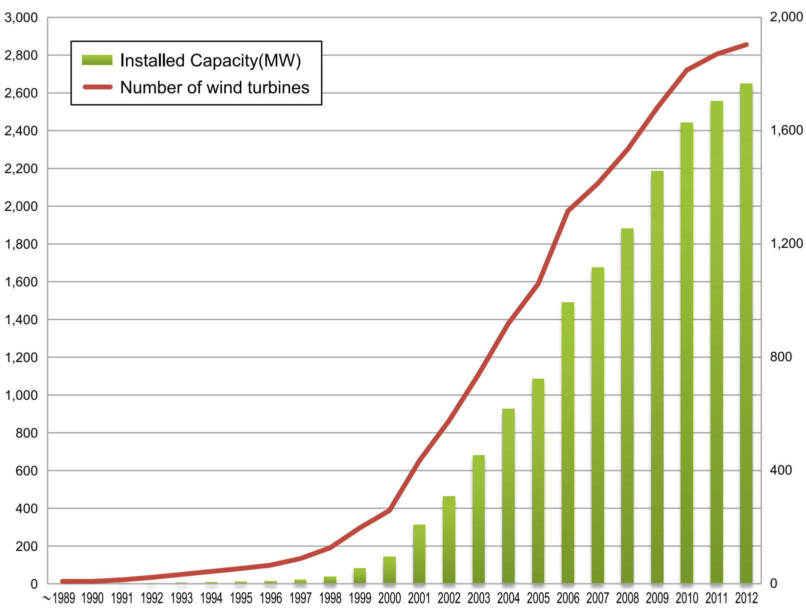
In Japan, there are aspects of these challenges that differ widely from the natural and social environments and other conditions surrounding offshore wind power development in Europe. Consequently, it will be essential to utilize the proving research currently being advanced to establish low-cost offshore wind power generation technologies compatible with the conditions in Japan.

▲ Wind condition observation tower and wind turbine offshore Choshi (Chiba Prefecture)

▲ Wind condition observation tower and wind turbine offshore Kitakyushu City (Fukuoka Prefecture)

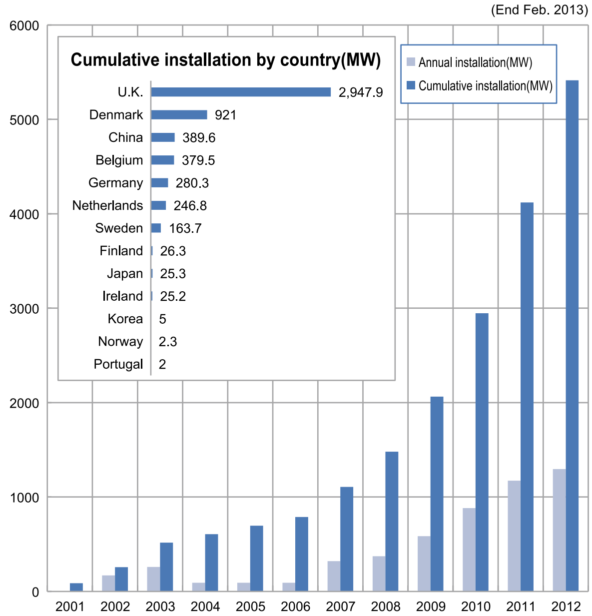
■ Installed Capacity and Number of Wind Turbines in Japan

NEDO (End April 2013)



■ Global Offshore Wind Power Capacity

GWEC (End Feb. 2013)



Forging the Foundation for Japan's Offshore Wind Power Generation Technology

Forging the Foundation for Japan's Offshore Wind Power Generation Technology

In Europe, the expression "Offshore is not offshore" is often used with regard to offshore wind power generation. The gist of this phrase stems from the fact that, various different types of offshore wind project exists in terms of water depth, distance from the shore and other marine conditions.

In Japan as well, with the different meteorological and marine conditions depending on sites, the demonstration project will be conducted on the Pacific (offshore Choshi) and the Sea of Japan (offshore Kitakyushu City).

In particular, Japan has no experience in offshore wind measurements for extended periods at high altitude. The investigation of offshore wind, waves, tides and other conditions is extremely important in the planning and designing of offshore wind power plants. This is why the measurements are going to be carried out for two years. Such measurement data will provide a precious source of information in the future formulation of technical standards for offshore wind power generation.

In the development of offshore wind turbines, the need also arises for development of technologies capable of providing countermeasures to salt damage, typhoons and lightning strikes, as well as adapting to other aspects of the harsh environments that exist in offshore water realms. In addition to this, access to offshore wind turbines is far more greatly limited than those to onshore wind turbines. Accordingly, research and development of the sophisticated operation and maintenance technology will be conducted in order to achieve high rates of operation.

In the establishment of environmental assessment methods, quantitative evaluations of marine organisms are the major concern. Realized through this work are methods for surveying bottom fish species for which samples cannot be obtained, as well as evaluation methods for fish school grouping effects.

In Japan, the development of offshore wind power generation has just begun. Nevertheless, the wind power generation technology cultivated onshore to date and the development of multi mega-size wind turbines in Japan, can potentially compete technologically against the European forerunners in this field.

Currently under development is a 7MW-class wind turbine equipped with a pioneering drive train (power transmission device). This new and truly globally unprecedented wind turbine will feature dramatic improvements in maintenance performance. The rich resources of Japan's manufacturers are being mobilized in this system, while cutting-edge overseas technologies are also incorporated into the mix. As a result, there is growing promise for this wind turbine to surpass the levels achieved by overseas rivals currently at the industry forefront. Such initiatives, meanwhile, suggest one possible direction for the technological development to be followed from here on.

Masaharu Itoh, Senior Researcher, New Energy Department, NEDO

Coordinator of wind power at the NEDO New Energy and Industrial Development Department from April 2006; assumed current post in October 2009.

(Left)Yuichiro Yamazaki, Deputy Director, Manager of offshore Kitakyushu City, Wind and Ocean energy group

(Right)Takashi Ohshige, Manager of offshore Choshi, Wind and Ocean energy group

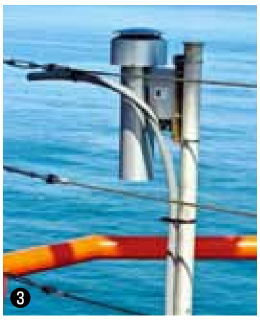
▲ Installation of the wind condition observation tower (offshore Kitakyushu City)

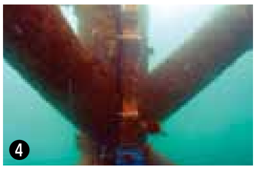
▲ Proving areas (offshore Choshi in Chiba Prefecture, offshore Kitakyushu City in Fukuoka Prefecture)

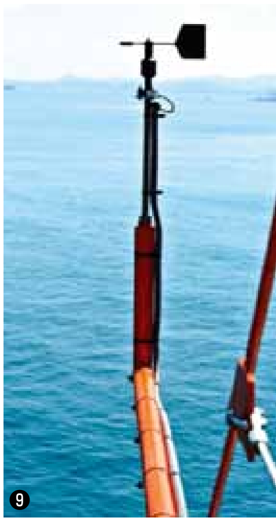
▲ Installation of the wind condition observation tower (offshore Choshi)

Offshore Kitakyushu City Wind condition observation tower measuring system

① 3-cop anemometer
② Ultrasonic wind vane and anemometer
③ Hygrothermometer
④ Sea surface thermometer
⑤ Barometer
⑥ Rain gauge
⑦ Hydrographic gauge
⑧ LIDAR (Light Detection and Ranging) (remote wind condition measurement instrument)
⑨ Arrow type wind vane







Amidst Global Competition, National Leadership Needed to Cultivate the Offshore Wind Industry

Completed in October 2012 was the wind turbine for an offshore wind power system offshore of Choshi in Chiba Prefecture. Preparations are currently being advanced to kick off the generation of this power from 2013. As such events unfold, we spoke with Professor Takeshi Ishihara of the University of Tokyo and "Research and Development of Offshore Wind Power Generation Technology" Project Leader, about his hopes for the fruits to be obtained from this project and the outlook for further progress in this field.

Takeshi Ishihara
NEDO "Research and Development of Offshore Wind Power Generation Technology" Project Leader
Professor, Department of Civil Engineering, School of Engineering, The University of Tokyo

Takeshi Ishihara ~ Profile~ Born in Beijing in 1962. After completing the doctoral course at Tokyo Institute of Technology (Department of Civil Engineering, School of Engineering), joined Shimizu Corporation. In 2000, appointed Associate Professor at The University of Tokyo (Department of Civil Engineering, School of Engineering), promoted to professor in 2008. Active in wind resources assessment, wind power forecasting, wind-resistant designs for wind turbine supporting structures, development of floating offshore wind turbine systems and other efforts.

Significance of Japan's First Offshore Wind Power Plant

Question(Q): Although in Japan wind power plants have primarily been constructed onshore to date, there are several offshore wind power plants as well.

Ishihara: The greatest characteristic of the wind turbines have been constructed in these projects is that, for both the facilities offshore from Choshi and Kitakyushu City, all of the constructions, operation and maintenance work stages were taking place offshore. While other offshore wind power plants have also been constructed facing the ocean, their construction and maintenance is performed onshore. From the perspective of all the work being done offshore, therefore, these projects are truly firsts for Japan.

Q: Is it feasible to utilize the know-how of Europe, which has been constructing and operating many offshore wind power plants ?

Ishihara: The ocean waters offshore from Choshi Chiba Prefecture are distinctive even in Japan for their fierce swell. The waters off Kitakyushu City in Kyushu, meanwhile, have earned the nickname of a "Typhoon Ginza" linked to the frequent passage and impact of typhoons there. With these natural conditions thus differing from those in Europe, there is a need to accumulate distinctive construction, operation and maintenance expertise for offshore wind power plants. It will be possible to use the know-how gained from these projects in the design and operation of future offshore wind power plants in Japan. In fact, we are steadily coordinating the information that must be proposed to the International Electrotechnical Commission (IEC) and other global standards.

Current Data as Cornerstone of the Future

Q: The trend toward large-size wind turbines is advancing worldwide. Will Japan also be moving to achieve larger size in these facilities?

Ishihara: It is significant that the 2.4MW wind turbines in these projects have been constructed with Japanese technology. Of course, we are facing the need to advance toward larger size from here on, in order to take greater advantage of the merits of offshore wind power. For that matter, the 100-meter height of the offshore observation towers in these projects represents the same altitude as 7MW wind turbine towers. What's more, the observation height of 200 meters is the same as the tip of blade for 7MW wind turbine. In that sense, the data collected from these projects can also be put to use in the quest to develop large-size wind turbines.

Gearing up to Realize Large-Scale Wind Farms

Q: What types of issues must be overcome for the use of offshore wind power generation to spread throughout Japan over the years to come?

Ishihara: The first such area involves achieving the infrastructure needed for offshore use. To enable the foundation, nacelle and other components of offshore wind turbines to be transported to their destinations will require the construction of adequate port facilities. Also needed, for the construction itself, will be large floating cranes, work barges and other vessels. Such infrastructures will likewise be vital in making the transition to commercial use of floating offshore wind power generation. The development of such supports will be difficult through the resources of the private sector alone, with government assistance also indispensable. Another challenge regards the creation of a domestic supply chain. Failure to achieve the capacity to develop, test and manufacture parts in Japan will impede the ability to compete in world markets.

Q: What is expected by NEDO from here on in this field?

Ishihara: Overseas, governments are setting targets for offshore wind power, preparing legal frameworks, developing infrastructure and otherwise mobilizing nationwide pushes to cultivate offshore wind industry. This trend is not limited to Europe and North America, with South Korea and other Asian nations also continuing to rapidly accelerate development in this sector. In my view, Japan needs to follow the lead of the West in setting high national targets, providing strategic support for putting needed infrastructure into place and other aspects of the technical development. From NEDO, therefore, we look forward to the organization exercising strong leadership in the quest to triumph in the emerging global competition.

Domestic First! Offshore Wind Power Generation to Commence

NEDO started to the operation of offshore wind condition observation towers and wind turbines in the waters offshore Choshi in Chiba Prefecture and Kitakyushu City in Fukuoka Prefecture.

These projects involve the establishment of the technologies needed to transmit the power actually generated by offshore wind turbines to the shore, for operation and maintenance of the wind turbines and other know-how critical for promoting introduction and expanded use of offshore wind power generation.

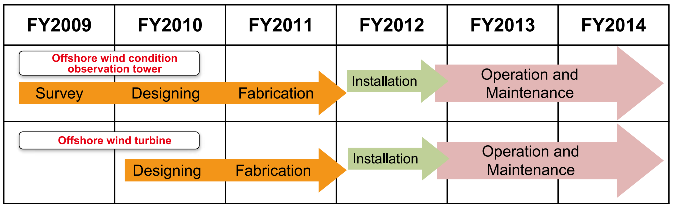
Furthermore, with Japan's first-ever domestic installation of offshore wind condition observation towers on the Pacific Ocean and Japan Sea sides, it will become possible to quantitatively evaluate the wind condition characteristics in these offshore environments.

In this section, to learn more about the NEDO "Research and Development of Offshore Wind Power Generation Technology" project, we explore the works offshore Choshi and Kitakyushu City, while speaking with the figures in charge of the local work.

Choshi

Started to the Operation of Offshore Wind Power Generation System!

■ Schedule



Proving Research Overview

NEDO launched the “Offshore Wind Condition Observation System Proving Research” project (offshore Choshi; contractors Tokyo Electric Power Company, the University of Tokyo) from fiscal 2009, and the “Offshore Wind Power Generation System Proving Research” project (offshore Choshi; joint researcher Tokyo Electric Power Company) from fiscal 2010.

In this proving research, a wind turbine, observation tower and other proving equipment are being installed offshore Choshi in Chiba Prefecture, within waters characterized by especially severe meteorological and marine conditions even within Japan. The work encompasses the development and offshore proving of safe foundation configuration, structure and other elements, in striving to establish methods for designing offshore wind power generation equipment suitable to the conditions in Japan.

In more specific terms, development is being undertaken of salt removal filters, heat exchangers and other optimum salt-resistant mechanisms for use in reducing the flow of salt into the nacelle in the harsh offshore environment, followed by proving in the ocean. Also under development is a foundation designed to use a pre-stressed reinforced concrete structure to curb cracking and lessen salt-damage deterioration. Through the offshore proving of these developments, design methods will be established for measuring the external force and dynamic behavior acting on the wind turbine and foundation, taking measurements of the soundness of machinery inside the nacelle and performing other tasks.

Also achieved will be the extension of inspection intervals through enhancement of remote surveillance and remote control functions, along with other optimum operation and maintenance methods for offshore wind turbines prone to be difficult to access.

Installation of the wind condition observation tower was completed in August 2012, and that of the wind turbine was completed in October 2012. Operation of Japan’s first demonstration test offshore wind power generation facility was started in January 2013.

WORK PROCESS (Offshore Choshi)

1 Environmental Impact Assessment

Preliminary surveys are conducted of organisms, scenery and other factors, with projections and assessments made of the impact on the environment to accompany installation of the offshore wind condition observation tower and wind turbine. The impact on the environment is also observed before and after the installation and during the operation of the offshore wind turbine, verifying the initial environmental impact assessment.

2 Construction of Foundation Structure

The foundation structure is designed and manufactured to support the offshore wind condition observation tower and wind turbine even within a harsh natural environment characterized by typhoons, earthquakes and other phenomena. The structure stretches well over 10 meters in height from the ocean floor to the water surface, and weighs several thousand tons.

3 Installation of Offshore Wind Condition Observation Tower

A steel tower reaching about 100 meters above the ocean, used to take measurements of wind direction, speed and other data at 10-meter intervals. Equipped with remote sensing technology, this will be Japan’s first domestic observation tower capable of observing wind conditions up to 200 meters above ground.

4 Installation of Submarine Cable

The installation of submarine power cable for transmitting to the electricity generated at the offshore wind turbine and supplying the power resource for the offshore wind condition observation tower, and the communications cable for transmitting observation results, wind turbine data and other information.

5 Installation of Offshore Wind Turbine

The wind turbine hub is located about 80 meters above the water surface, while the rotors are 92 meters in diameter. On the container facility (nacelle) used to hold the 2400kW generator, transformer and other equipments, action is being taken to prevent salt damage, condensation, corrosion and other problems.

6 Installation of Transmission and Transforming Facilities

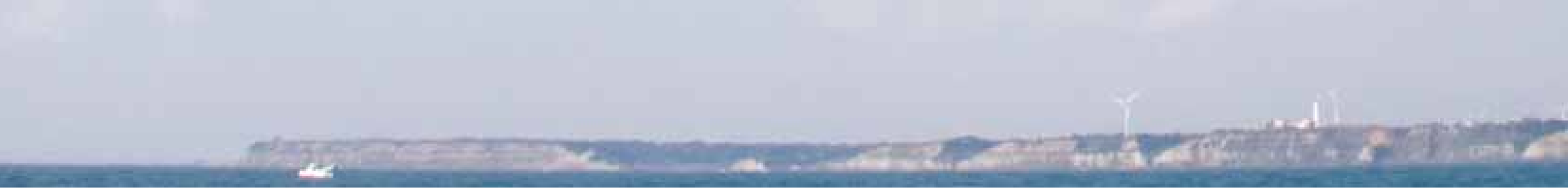
Equipment for transmission of the generated electricity was installed on land near the offshore wind turbine to change the voltage of the electricity generated by the offshore wind turbine and to connect it with or isolate it from the existing transmission grid.

7 Test Operation

After installation of all facilities is complete, test operation is conducted on each component, checking the power generation, observation, telecommunications and other equipments. In testing of the wind turbine in particular, the operation of the electrical system, safety equipment, brakes, pitch control and other areas is confirmed.

8 Commissioning

Over the period of approximately two years until the end of fiscal 2014, wind data will be measured at the observation tower, verification will be made of offshore wind turbine power generation performance, studies will be made of operation and maintenance performance and other data and know-how accumulated.



Conquering Waters Known for the Harshest Environment in Japan, Creating Model Case for Offshore Wind Power Generation

From the left: Professor Takeshi Ishihara of the University of Tokyo, Yukinari Fukumoto of Tokyo Electric Power Company, Hideo Tanaka of Kajima Corporation.

Trial-and-Error Process with Everything a "First"

"With each and every stage of the work being performed for the very first time, not only was the design time consuming, but the various different procedures also proved challenging." Reflecting back on this project was Yukinari Fukumoto of the Research & Development Center of Tokyo Electric Power Company (TEPCO). With this comprising Japan's first construction of an offshore wind turbine and offshore wind condition observation tower, the government authorities in charge of issuing approvals also had no working experience. As a result, inspections normally requiring one to two months to wrap up dragged on for between seven to ten months.

"We enlisted cooperation from Professor Ishihara of the University of Tokyo and other experts, and took the natural conditions in Japan into close account in assessing the performance of offshore wine turbines in Europe. In that way, we hammered out decisions on a steady stream of design requirements."

The most important points in undertaking the construction of an offshore wind turbine include assessing the impact on the environment and earning the understanding of the local residents. Notes Mr. Fukumoto, who paid any number of visits to fishermen's cooperatives and other local stakeholders to explain the project, stressed that the understanding and collaboration of the local community is indispensable for the success of such an undertaking: "We benefited from the cooperation of the local citizens on various different fronts, and feel extremely grateful for that precious support."

Surmounting Difficulties with Ideas and Experience

Recalls Hideo Tanaka, Director of the TEPCO Offshore Wind Power Generation Work Office of the Tokyo Civil Engineering Branch of Kajima Corporation, the general contractor handling the actual construction work: "The work proved far more formidable than expected, and posed a steady series of difficulties." The construction took place in the waters off of Choshi in Chiba Prefecture, an environment known for strong surging waves from the churning intersection of the Oyashio and Kuroshio currents. There was thus a need to complete work on the foundation before arrival of the typhoon season of June-August, with ocean floor dredging work begun from February 2011. The following month, however, the Great East Japan Earthquake struck.

The completed foundation was loaded onto a floating dock and transported, then lowered from a crane barge for installation at the prescribed location.

Mr. Tanaka looks back on that event: "The site of the dredging work was hit by a tsunami, with Kashima Port (where the foundation was being manufactured) also suffering damage. In the wake of that disaster, we suspended construction and supplied vessels, materials and other resources to the areas stricken by the quake and tsunami to support the recovery effort."

The foundation work in the waters off of Choshi was eventually resumed in February of 2012. After dredging the ocean floor down to the bedrock, there was a need to spread rocks of various different sizes to level the seabed surface.

"While we used a specialized construction machine known as an underwater backhoe, visibility of only about 30 centimeters left us no other choice but to advance the construction manually by divers. Due to the peculiar wave swells that occur offshore from Choshi, in addition to moving stones the divers also needed to take every effort to avoid getting swept away themselves. Although everyone in the water was a veteran, we were informed later that they had never before experienced such a harsh work site. Thanks to the marvelous efforts of those divers, however, ground leveling work demanding precision of ±5 centimeters was successfully completed in June."

But this was not the end of the struggle, with demanding work continuing after the leveling of the ocean floor as well. The caisson, a massive box-like structure comprising the foundation of the wind condition observation tower and wind turbine, is a concrete structure shaped like a conical flask, stretching 21 meters in diameter on the ocean floor and weighing some 2,300 tons. This huge structure needed to be installed on the seabed at a depth of approximately 12 meters.

Continues Mr. Tanaka: "The crane barge used in this project was an all circling type at the largest class available in Japan. But even so, it could only suspend up to 1,600 tons. Adopted to deal with that situation was the method of halfway submerging the caisson, then using the combination of buoyancy and the crane to lower it down. Furthermore, because using the crane to lower the caisson from the front of the barge would cause the vessel to be hit by the full impact of the waves, it was lowered from the middle of the barge (where the rolling was smaller). The distance between waves became less than the length of the hull, and we waited for the moment at which the vessel stabilized to lower the caisson.

"The days turned into a repeated process of checking out the weather forecasts. Early each morning we would confirm the wave conditions, and then try to choose the optimum timing for sending out the barge. After such a prolonged struggle, there was a sense of genuine exhilaration when we finally succeeded."

Once the caisson had been installed at the prescribed location, it was filled up with slag. With a completed weigh of around 5,400 tons, the caisson now supports the wind condition observation tower, wind turbine and other components.

Work Experience and Proving Data as Assets

The wind condition observation tower, wind turbine and other project components have been constructed with a Self Elevating Platform (SEP) barge. SEP barges are equipped with four elevator legs that are set into the ocean floor and used to lift the hull up from the ocean surface. This makes it possible to perform construction work offshore without being impacted by waves.

Notes Mr. Tanaka: "Thanks to the SEP barge, the work proceeded smoothly from the foundation construction on. After resuming the project in February 2012, work continued at the installation site without taking a single day off."

Installation of the wind condition observation tower in August, the wind turbine in October, 2012, and started full-scale operation from March, 2013.

Mr. Fukumoto reflects on the work: "In the manufacture of the foundation, it was a struggle to locate a port from which the massive foundation could be carried out to the work site. This keenly drove home the need for port facilities capable of being put to use in the wind turbine construction."

Mr. Tanaka also stressed the need to develop infrastructure in the quest to promote use of offshore wind power generation: "To conduct work operations in oceanic environments, there is a need for special-purpose vessels appropriate for the open seas. While offshore locations are suitable for the construction of large-scale wind turbines, the development of large-size wind turbine specialized vessels for use in such work is vital."

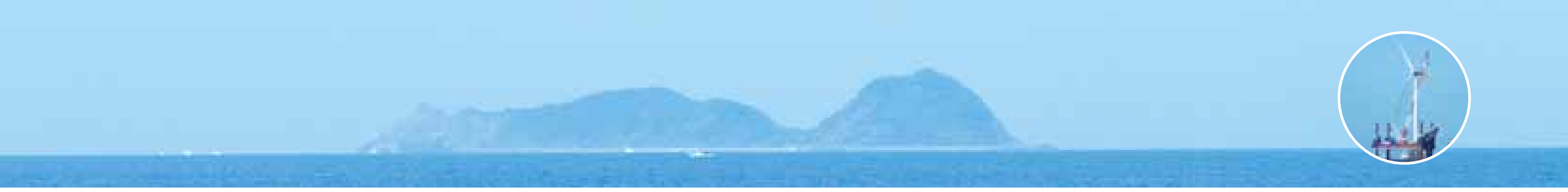
Hopes are running high that the accumulated experience obtained from construction of the wind turbine offshore from Choshi, an area said to pose the most severe work environment throughout Japan, and the data to be generated from here on will play a key role in expanding the use of offshore wind power in Japan.

Yukinari Fukumoto,
Offshore Wind Power Generation Technology Group Manager, Research & Development Center, TEPCO

Hideo Tanaka,
TEPCO Offshore Wind Power Generation Work Office Director, Tokyo Civil Engineering Branch, Kajima Corporation

The nacelle and all other components are loaded onto the SEP barge used to assemble the tower and wind turbine.

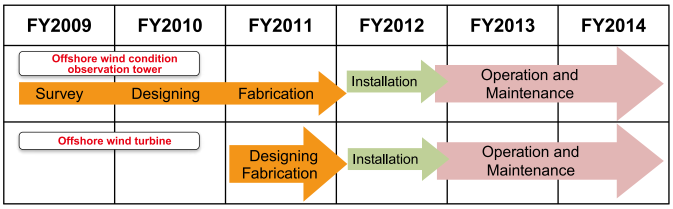

NEDO



Kitakyusyu

Started to the Operation of Offshore Wind Power Generation System!

■ Schedule



Proving Research Overview

NEDO has been advancing the "Offshore Wind Condition Observation System Proving Research" project (offshore from Kitakyushu City; contractors Electric Power Development Co., Ltd., Port and Airport Research Institute, ITOCHU Techno-Solutions Corporation) from fiscal 2009; and the "Offshore Wind Power Generation System Proving Research" project (offshore from Kitakyushu City; joint research contractor Electric Power Development Co., Ltd.) from fiscal 2011.

The former project consists primarily of installing an observation tower, and then developing a grasp of the offshore meteorological and marine characteristics. Along with this, a simulation system will be built for the sake of appropriately estimating the meteorological and marine conditions in these waters, with verification advanced using actual observation data. The latter project is necessary for the establishment of construction methods taking into account the weather and oceanic phenomena peculiar to Japan, as well as power generation plans and operation methods appropriate for use offshore. It is being advanced with the purpose of compiling data contributing to the promotion of offshore wind power generation in the future.

The substructure and generator type of the wind turbine offshore of Kitakyushu City differ from those of the installation offshore of Choshi in Chiba Prefecture. Comparing the data collected at both sites on the forces acting on the substructures and on the operation and maintenance of the wind turbines will allow verification of the offshore wind power generation appropriate to conditions in Japan. Installation of the monitoring instruments was completed in June 2012 for the wind observation tower offshore of Kitakyushu City in Fukuoka Prefecture, and observation of wind and ocean conditions started in October of that year. The data were used to forecast the meteorological and oceanographic conditions during winter on the Sea of Japan , and the offshore working schedule such as dates and hours as well as the number of working days were verified as necessary until installation of the offshore wind turbine was safely completed in March 2013. Operation started in June 2013.

WORK PROCESS (Offshore Kitakyusyu)

1 Environmental Impact Assessment

Biological, visual, and other impacts related to installation of the offshore wind condition observation towers and offshore wind turbine generator have been investigated to predict and assess environmental impacts. Studies are conducted before, during, and after operation of the offshore wind turbine.

2 Construction of Substructure

The hybrid gravity-type, which combines concrete and steel, was adopted for the substructure. This type of structure has outstanding stability and wave resistance.

3 Installation of Offshore Wind Condition Observation Tower

The observation tower rises about 80 m above the ocean surface and was installed by using a large floating crane. Wind direction and speed are measured at 10 m intervals.

4 Installation of Steel Pole

To connect the submarine cable to the switching facility installed on land, a steel pole is installed in the sea near the land and an overhead cable is adopted for the connection.

5 Laying of Submarine Cables

A cable layer is being used to lay cables for transmitting power generated by the wind turbine to shore, supplying power to the measuring instruments for the offshore wind condition observation tower, and communicating observational data and other information.

6 Installation of Offshore Wind Turbine

The center of the rotor is about 80 m above the ocean surface and its diameter is 83 m. The 1980 kW generator, transformers, and other equipment are installed on the wind turbine. Measures required for offshore siting, including salt damage countermeasures, have been implemented.

7 Installation of Switching Equipment

The switching equipment is installed on land and used for transmitting the electricity generated by the offshore wind turbine. It is used to connect the transmission line to and disconnect it from the existing electric power grid.

8 Commissioning

Until the end of FY2014, we will collect wind condition data from the offshore wind condition observation tower, verify the generation performance of the offshore wind turbine, and review the technologies applied to operation and maintenance, accumulating data and know-how.

Mobilizing Structural Designs and Construction Methods Based on Considerations for the Extreme Weather Conditions on the Japan Sea During Winter

▲From the left: Shusaku Nakashima and Yutaka Yoshimura of Electric Power Development Co.; Sumihisa Kozono and Noboru Matsumoto of Penta-Ocean Construction Co.
►Installation of the hybrid gravity type substructure and the offshore wind turbine.

Japan's First Offshore Wind Condition Observation Tower

On June 30, 2012, Japan's first domestic offshore wind condition observation tower was installed offshore from Kitakyushu City in Fukuoka Prefecture. "We were not blessed with good weather during June off the coast from Kitakyushu City, on the contrary, experienced unseasonable typhoons and rough waters. Consequently those brought additional days, which were not considered in the planed schedule, so as to keep the works safe. However, we succeeded in the installation of Japan's first offshore wind condition observation tower." Explaining the project with a considerable look of relief was Yutaka Yoshimura, Assistant Director of the Wind Power Business Office under the Environment & Energy Business Department of Electric Power Development Co., Ltd. – the company that carried out the project.

Mr. Yoshimura points out the importance of gaining firm local parties backup: "The biggest factors were the understanding of the leaders of the local fishery cooperatives, and the swift and flexible responses taken by Kitakyushu City on the use of the port area and other key matters."

With regard to technical difficulties as well, Mr. Yoshimura looking back: "From the aspect of structural function, precision control was carried out for both the observation tower and wind turbine within a range of ±5cm on the foundation, and for the incline within 0.30 degrees for the tower and 0.25 degrees for the turbine. It was so serious to fulfill those requirements from precast of structures and the offshore construction method. We performed a long series of studies, and finally succeeded in making the grade."

Adoption of "Hybrid Gravity Type Substructure"

A distinctive feature of the Kitakyushu City offshore project was adoption of the "hybrid gravity type" as a substructure for both the offshore wind condition observation tower and wind turbine.

Explains Mr. Yoshimura: "The types available for substructures are gravity type, monopole, jacket structure and other varieties. In this project, we adopted the hybrid gravity type, which applies the construction merits of the gravity type and the advantages of the jacket type primarily in terms of structural characteristics. This is a structure created by installing a jacket integrated with deck slab concrete on a foundation of rubble stones on the sea bed. "

Mr. Yoshimura goes on to describe the merits of the hybrid gravity type: "First, on the structural side, by making the submerged portion with a permeable structure by the frame members, it is possible to greatly reduce the wave force compared to the general gravity type. For construction efficiency, after placing the rubble stones, precasting is performed (assembly and manufacturing work finished ahead of time at the factory), effectively integrating the deck slab concrete and jacket. A 4,000-ton class floating crane is then mobilized to install the structure, greatly reducing the volume of work to be conducted offshore. Using this hybrid structure, which combines steel and concrete, it becomes possible to maintain stability and achieve a tough structure.

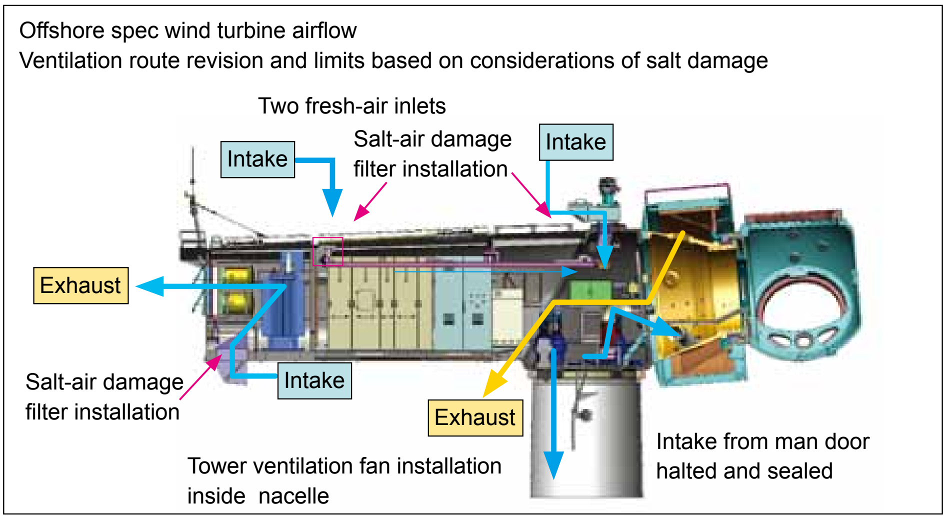
Functions Demanded of Offshore Wind Turbine

One of the characteristics of the wind turbine installed in the Kitakyushu City offshore project is adoption of a "gearless type" generator differing from the variety used in the Choshi undertaking. According to Shinichi Inaba, Section Manager at the Wind Power Business Office of Electric Power Development Co., Ltd.: "The gearless type wind power generator manufactured by The Japan Steel Works, Ltd. adopted in this project does not use a gearbox and is comprised of a comparatively small number of parts. As a result, it offers advantages of fewer breakdowns and lower maintenance costs than products of other types."

At Electric Power Development Co., Ltd., a gearless wind turbine generator has been already adopted at Kitagata Wind Power Generation

Co., Ltd. in Awara City, Fukui Prefecture. In this latest project, however, salt-air damage countermeasures have been employed on a priority basis in view of the offshore installation status.

Continues Mr. Inaba: “Salt-air damage countermeasures are being adopted primarily from the two aspects of coating and airflow. For the coating, a heavy-duty salt-resistant paint is applied on the tower, hub, nacelle, sub-frame and generator. To normally cool a wind turbine, outer air is taken from the lower part of tower and sent to the nacelle in order to cool down the drive section. Offshore, however, taking air from the tower’s lower section will result in air containing salt passing through the interior of the wind turbine. For that reason, the method was adopted of reversing the airflow, and only taking the air after filtering it through a salt removal filter from the upper part of the nacelle.”



Offshore spec wind turbine airflow
Ventilation route revision and limits based on considerations of salt damage

Sumihisa Kozono, Director of the Hibikinada Observation Tower Work Office, Kyushu Branch of Penta-Ocean Construction Co., Ltd., during February to March 2013 when the company coordinated this work phase, describes the challenges of implementing the wind turbine installation work under adverse conditions.

“At the time, we dispatched vessels offshore for the wind turbine substructure inspection work. The conditions were such that the impact could be felt even at wave levels of around 60 centimeters. We anticipated one to two meter waves around February and March, so we needed to conduct the work with even greater caution at that time. However, because the installation was conducted with an SEP barge, the waves became problematic primarily while transporting workers. With regard to the wind turbine installation, in contrast, wind poses the greatest challenge. In particular, with the work to be carried out in the Sea of Japan during the winter months, we considered work plans amidst conditions that were expected to become even more severe.”

Offshore Wind Turbine Installation During Severe Winter

Installation of the offshore wind turbine off the coast of Kitakyushu City, Fukuoka Prefecture was completed on March 23, 2013. Mr. Yoshimura, who directed the project, comments: “The main work at sea to install the wind turbine began at the end of February 2013 and construction work in the Sea of Japan in winter was extremely challenging. The efforts of the project team contributed to the safe completion of the wind turbine installation.” He then recounted: “There are very few prior cases of construction work conducted during the winter in such a short time. Detailed work procedures were examined for the wind turbine installation work, including temporary facilities. Wave and wind speed forecasts were also made several times a day and work procedures were discussed by the project team and revised as necessary. By doing so, we were able to install the wind turbine safely and with the required precision.”

Mr. Kozono, who managed the site work, comments: “Although a SEP barge was used for the wind turbine installation, I believe that the problems unique to offshore wind turbine installation became clear, such as forecasts of wave height and wind speed, which were needed for safe transport of workers to the SEP barge and installation of the wind turbine. During construction work, the results of the forecasts of wind speed and wave height were used as the basis for judging whether or not work could be conducted the next day. The application of detailed forecasts allowed reliable, safe, and efficient execution of construction work and allowed us to safely complete the installation of the wind turbine during the severe winter.”

After confirming the various operations of the offshore wind turbine generator, it is scheduled to start operation in June 2013 after commissioning test. This will initiate the vital task of collecting data to prepare for full-scale deployment of offshore wind power generation.

Finally, we asked Mr. Yoshimura about the significance of this project. “It is extremely significant that we are able to comprehensively collect data for the first time under the extreme natural conditions of the Sea of Japan in winter. In this project, we will collect data from 15 m below the ocean to 80 m above the ocean surface by monitoring meteorological and oceanographic conditions, using the monitoring system installed on the offshore wind observation tower. This data will be extremely important for future offshore wind power generation. Competition for offshore wind power generation has intensified worldwide, and expectations for it have increased rapidly in Japan since the Tohoku Earthquake disaster. We would like to be able to meet those expectations.”

Yutaka Yoshimura,
Assistant Director, Wind Power Business Office, Environment & Energy Business Department,
Electric Power Development Co., Ltd.

Shinichi Inaba,
Section Manager, Wind Power Business Office, Environment & Energy Business Department,
Electric Power Development Co., Ltd.

Sumihisa Kozono,
Director, Hibikinada Observation Tower Work Office, Kyushu Branch, Penta-Ocean Construction Co., Ltd.

Targeting the World Market with 7MW-Class Mega-Size Wind Turbines

In the quest to scoop the world in commercializing 7MW-class plus mega-size wind turbine systems, NEDO has been advancing the "Mega-Size Wind Power Development System Technology Research and Development" project since fiscal 2011. The goal of this effort is to achieve development that integrates drive trains (power transmission devices that convey blade rotations to generators) with structures high in reliability and excelling in maintenance performance, long-wing blades high in rigidity and low in weight and remote monitoring systems capable of forecasting parts breakdown and proper maintenance timing. In this section, we trace the progress being made in the development of a 2.4MW-class new model drive train, for which proving tests are currently being advanced at the Yokohama Dockyard and Machinery Works (Kanazawa Plant) of Mitsubishi Heavy Industries, Ltd.

● Into the Era of Size-Based Competition

While wind turbine is attracting keen attention as a source of clean energy, emerging as a major theme in the field of offshore wind turbine is reducing the cost of generating electricity. Raising the rated power of wind turbine makes it possible to reduce the number of turbines installed. For this reason, the move toward large-size wind turbines has become the global trend. In this regard, because large wind turbines face restrictions on transportation, installation and other aspects in onshore environments, their application in offshore wind turbine is anticipated to increase from here on.

Masahide Umaya, General Manager of the Offshore Wind Turbine Project Development Department under the Wind Turbine Business Division of the Power Systems Business Headquarters at Mitsubishi Heavy Industries, explains the project aim:

"At present, wind turbine manufacturers in countries around the world are primarily pursuing production of 3-4MW-class turbines. Even among turbines for which upcoming development has been announced, almost all of the models range from 5 to 6MW in class. In this business, we are setting our sights on development of 7MW-class wind turbines – the largest size within the sphere for which commercialization is feasible."

● The Technology to Realize Large Wind Turbines

Points out Fumio Hamano, Department Manager in charge of technology at the Offshore Wind Turbine Project Development Department: "The reality is that it is difficult to realize mega-size wind turbines simply by raising the scale of the structures. As a case in point, systems known as step-up gears are necessary in the wind power generators that comprise mainstream use at present. With mega-size wind turbines, however, the actual gear mechanisms used in such step-up gears also become massive in size. This increased scale makes them more prone to breakdown, while limits have appeared on the technology and cost fronts as well." As the technical development to be required for mega-size wind turbines, Mr. Hamano cites three key areas: "Hydraulic drivetrains," "long-wing blades" and "remote monitoring systems."

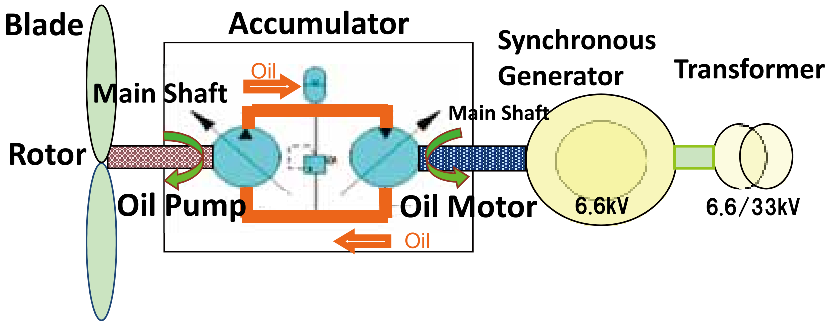
Hydraulic Drivetrain: Striking a Balance Between Reliability and Durability

Indispensable in wind power generation are "drive train" power transmissions systems for conveying wind turbine rotations to the generators. With hydraulic Digital Displacement® Transmission (DDT), the scheme is adopted of initially transforming wind turbine rotations into oil flow at the hydraulic pump, and then transmitting that flow to the hydraulic motor to rotate the generator. Introduced at Mitsubishi Heavy Industries is hydraulic DDT control technology developed by Artemis Intelligent Power LTD., a venture company in Edinburgh, Scotland in the United Kingdom, to advance development of drive trains for use in offshore wind turbines.

Mr. Hamano continues: "With hydraulic DDT, hydraulic pump and hydraulic motor cylinders use oil to draw out energy. With other types, major breakdowns create the need to replace the entire system. With hydraulic DDT, however, it is possible to cope with such situations through partial replacement of the hydraulic components. In addition to this, another advantage is the ability to readily respond to the need for greater output by simply increasing the number of cylinders or other small parts, raising the number of hydraulic motors or taking other steps that facilitate the shift to such higher output. Yet another major merit from the standpoint of supplying electric power is that even if one hydraulic motor breaks down, as long as the other motors are operational output will never drop to zero."

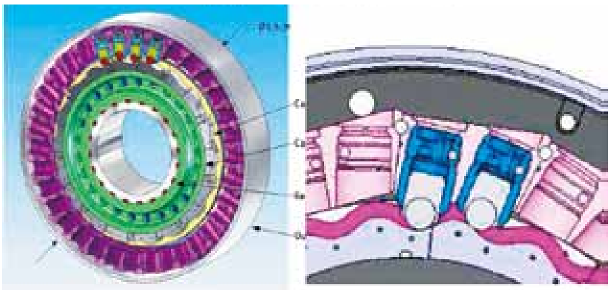
Engineering meeting of hydraulic DDT 7MW shop test between Mitsubishi Heavy Industries and Artemis Intelligent Power

Key Technology ①

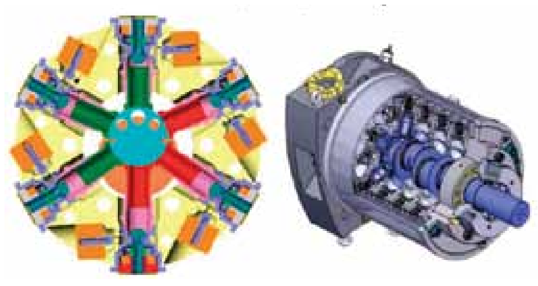


Wind energy will be converted to high pressure oil by oil pump. Then high pressure oil energy will be converted to electricity by oil motor.
(Top) Operating principles of Digital Displacement® Transmission
(Bottom left) Operating principles of Digital Displacement® Pump
(Bottom right) Operating principles of Digital Displacement® Motor

Digital Displacement® Pump (DDP)



Digital Displacement® Motor (DDM)



Operating Principle of DDP

The blades catching the wind rotate slowly at 10 revolutions per minute, and this rotational force is transmitted via the main shaft to the wave-shaped structure shown in red in the figure above. When the wave-shaped structure rotates, the cylinders (42 by 4 rows) attached above this move up and down; this produces a high hydraulic pressure of about 350 times the atmospheric pressure. The high-pressure oil is delivered to the hydraulic motor through a pipe. Because the hydraulic pump and hydraulic motor are connected by a pipe, this allows a high degree of freedom in placing equipment inside the nacelle. Thus, compared to a wind turbine where the blades are directly connected via the main shaft to the generator, there is a high degree of freedom in placing equipment inside the nacelle. In addition, because the number of cylinders used can be adjusted in response to wind speed, high energy transmission efficiency from the blades to the generator can be achieved by stopping some of the cylinders when the wind is weak.

Operating Principle of DDM

The hydraulic motor has 6 cylinders arranged radially, and a 7 MW hydraulic wind turbine has 6 rows of 2 hydraulic motors. The high pressure produced by the hydraulic pumps rotates the hydraulic motor; this allows rotation speed and torque of the generator axis to be finely adjusted. This feature makes it possible to use a general-purpose synchronous generator, identical to that of a conventional thermal power station, in a wind turbine. For this reason, the hydraulic motor can directly and finely adjust the voltage, frequency, and power factor of the generated electricity, which are directly linked to electric power quality. The advantage of this is that power converters, which are required in conventional wind turbines, are unnecessary in hydraulic wind turbines.

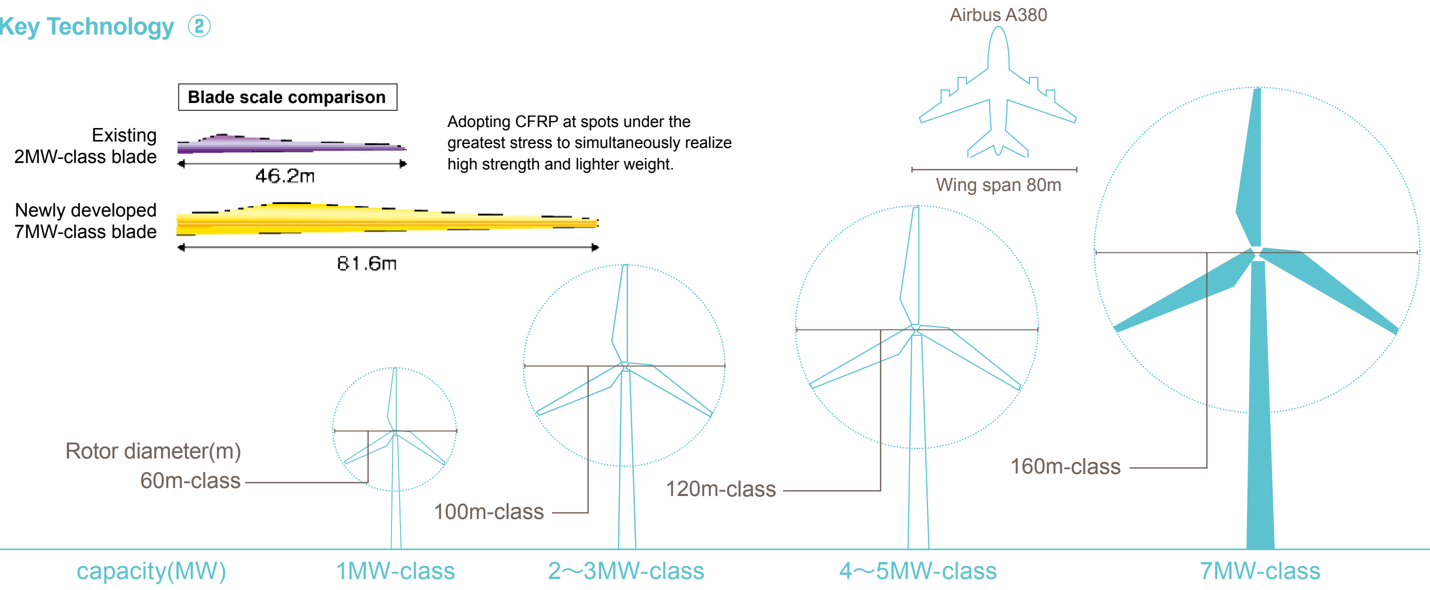
Long-Wing Blades: Realizing High Output and Availability

Increasing the size of wind turbines creates the need to also extend the length of the turbine blades. Because blade length exceeds 80 meters with 7MW-class wind turbines, the degree of bending from wind also rises, with the strength of conventionally used glass fiber reinforced plastic (GFRP) unable to endure.

According to General Manager Umaya: “Although carbon fiber reinforced plastic (CFRP) is well suited for lightweight, high-strength blade materials, the fact that the cost of this type of plastic is 10 times that of GFRP impedes its use in large quantities. We targeted that

Manufacture of the first blade
(Left) Moulding work of the first blade at blade manufacturing shop
(Right) Complete moulding of the first blade of 81.6m length

Key Technology ②



Blade lightning test
(Top) Lightning point receptor test
(Bottom) Arc discharge test

situation by utilizing CFRP for one part of the blades in striving to raise the strength level."

In addition to raising strength and reducing weight, there is yet another issue that must be resolved to pave the way for use of long-wing blades. This refers to the need to devise effective countermeasures for lightning strikes, salt damage and wear.

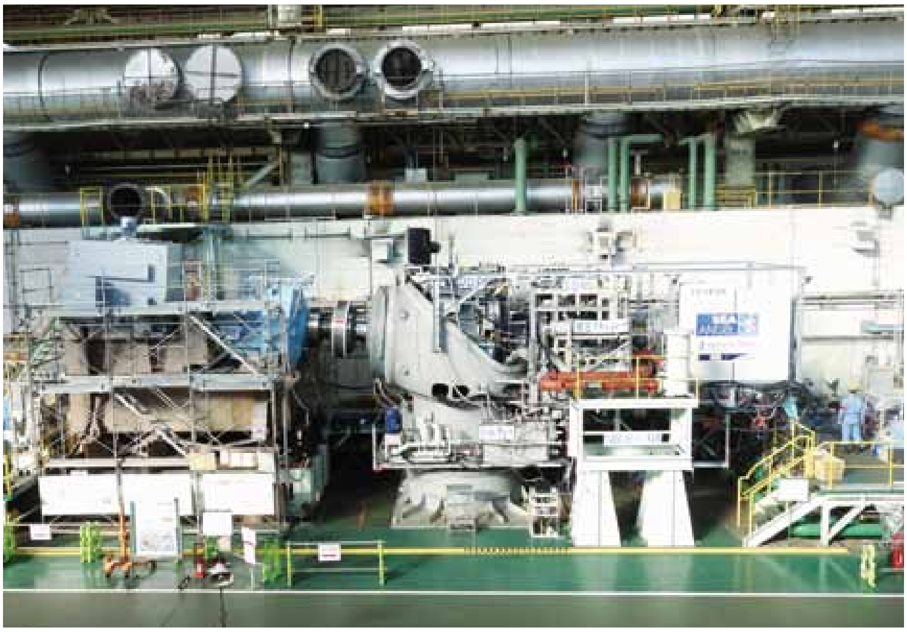
Mr. Hamano explained the features of the blades: "Because CFRP, the main structural material of the blades, acts as a conductor, if there is a large lightning strike, the large current flowing through the CFRP will cause a breakdown. So we have adopted a structure in which copper mesh is attached to the blade surfaces to allow the electric current to escape. In addition to verification by analytical techniques used for lightning-resistant design of aircraft wings, a verification test of this structure has been conducted with current flow and energy exceeding the most severe official standard, IEC Level 1. We have confirmed that the copper mesh can transmit current with the CFRP remaining in good condition. In lightning-resistant design, it is important for the receptors installed at the tips of the blades to reliably capture lightning. We have conducted lightning receptor tests with exposure to lightning from every possible angle and achieved a 100% capture rate." In addition, "Because the velocity at the blade tip climbs to about 300 km/h in mega-size wind turbines, normal paint will peel off when raindrops strike at this speed. In addition, exposure to sunlight for long periods reduces the strength of the paint owing to the effect of ultraviolet light. Thus, we have conducted durability tests that assume UV damage and high-speed raindrops and selected high-durability coatings. So mega-size blades are literally nuggets of intellectual property and know-how." General Manager Umaya emphatically explains the recent status of development: "We completed test production of the world's largest class large-scale wind turbine blade. At the end of May 2013, the completed blade was transported from Sassnitz, Germany across land by a special trailer and then transported by ship to a test facility in Germany. We have begun preparations for various tests to be conducted from July 2013."

Remote monitoring system: Intelligent Systems for Predicting Breakdowns

Mr. Umaya, who points out that the key to successful operation of offshore wind turbines lies in mounting effective responses to maintenance and troubleshooting, stresses the importance of predicting breakdowns: "In the case of offshore wind turbines, we operate on the assumption that if a breakdown occurs during the winter, the environmental conditions will render it impossible to bring work vessel alongside the turbine at that time of year, delaying repairs until the summer of the following year. In view of that, it becomes critical to have a remote monitoring system that enables such breakdowns to be predicted in advance."

"At Mitsubishi Heavy Industries," continues Mr. Umaya, "The know-how cultivated in Power plant management is applied in exercising effective control over mega-size offshore wind power generation systems.Breakdowns are predicted by accessing various types of data from the sensors strung around wind turbines. We are confident that such maintenance and control technology will also emerge as a major forte for Japan."

The first blade shipping from blade manufacturing shop to test shop
(Top) Lifting the first blade for test shop
(Bottom) The first blade loaded into trailer to quay side



Hydraulic DDT nacelle was loaded to 2.4MW class wind turbine tower top after shop test
(Top) Hydraulic DDT nacelle shop test.
(Right) Transportation from test shop to wind turbine test site and power generation test of 2.4MW class wind turbine

● First to United Kingdom, then to World Markets

"Demonstration tests for the 2.4 MW class wind turbine with the hydraulic DDT will be conducted at the Kanazawa Factory. However, before installing the hydraulic DDT on a wind turbine, it is necessary to confirm stable operation and reliability of moving parts, and to adjust the timing of the opening and closing of valves for optimal operation, by using a newly developed test apparatus to conduct separate tests of the hydraulic pump and hydraulic motor. Therefore, the hydraulic DDT was assembled inside the factory for overall tests at the factory. We conducted tests of the automatic starting function, electric power grid synchronized connection function, and confirmation of the safety shutdown function for abnormal events under various plausible wind conditions, and confirmed that the overall efficiency of the hydraulic system was higher than the target value. From December 2012 onward, after installing the hydraulic DDT in the nacelle at the top of a 2.4 MW class wind turbine at the Kanazawa Factory, we have been conducting comprehensive tests with an actual wind turbine." Assistant General Manager Masayuki Mukai of the Offshore Wind Turbine Development Project, who explains the progress of the program, then discusses future developments: "During 2013, we plan to conduct demonstration testing of the 7 MW class hydraulic DDT in U.K., as we are seeking to first supply wind turbines to U.K.. Apart from U.K., we also have plans for offshore wind turbines off the coast of the North Sea, the United States, China, and other locations. Our goal is to present proposals for the introduction of mega-size wind turbines built with Japanese expertise." Regarding the 7 MW mega-size wind turbine targeted for world markets, General Manager Umaya explains with a smile: "Because the many small cylinders (330/150 CC) that compose the hydraulic pump and hydraulic motor are like angels, it has been named SEA ANGEL® , with the hope that the hydraulic technology for offshore wind turbines that require high reliability will contribute to achieving a low-carbon society."

SEA ANGEL OFFSHORE WIND

7MW offshore wind turbine "SEA ANGEL®"

Offshore Wind Turbine Project Development Department,
Wind Turbine Business Division, Power Systems Business Headquarters,
Mitsubishi Heavy Industries, Ltd.

Masahide Umaya,
General Manager

Fumio Hamano,
Manager in Charge of Technology

Masayuki Mukai,
Assistant General Manager

Installation of the offshore wind condition observation tower (offshore Choshi), August 2012

Installation of the offshore wind turbine (offshore Choshi), October 2012

Installation of the offshore wind condition observation tower (offshore Kitakyushu), June 2012

Offshore wind turbine (offshore Kitakyushu), March 2013

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