DEVELOPMENT AND CONSTRUCTION OF FLOATING SUBSTATION

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Japan Marine United Corporation has developed, designed and constructed the world's first floating substation for wind farm off the coast of Fukushima. To meet the requirements of the floating substation, e.g. reduced vessel motions, sufficient stability, etc., we have applied several unique technologies such as the advanced spar concept. And, in 2013 summer, we installed floating substation at off the coast of Fukushima. In this paper, we describe about the concept and characteristic features of floating substation. During the construction, we applied newly and unique method to construct (e.g. mega block erection, suspended dock out) because of the unique floaters shape. These methods are also described in this paper.

Keywords: substation, wind power, offshore wind, offshore structure

INTRODUCTION

General

In recent years, a social demand for introduction of renewable energy is increasing because of rising conventional fossil energy resource and the nuclear power plant accident. For example, in the study of potential for renewable energy introduction published by Ministry of the Environment [1], Japan's potential for introduction of renewable energy is estimated at more than 2 million MW. Among them, the potential for wind energy is about 1.9 million MW and it is over 10 times the potential for introduction of the other renewable energy sources. Furthermore, wind energy can be divided in onshore and offshore, the potential for introduction of offshore wind energy is estimated at about 1.6 million MW. In other words, 80% of the potential for introduction of renewable energy in Japan are occupied by offshore wind energy.

Fukushima FORWARD

For the reconstruction of Fukushima Prefecture severely hit by the Great East Japan Earthquake and the Fukushima nuclear power plant accident at 2011, the government of Japan started the experimental research project of the world's first floating offshore wind farm. This project named as "Fukushima FORWARD (Fukushima Floating Offshore Wind Farm Demonstration Project)" is conducted by the consortium made up of Marubeni Corporation (project integrator), the University of Tokyo (technical advisor), Mitsubishi Corporation, Mitsubishi Heavy Industries, Ltd, Japan Marine United Corporation, Mitsui Engineering & Shipbuilding Co., Ltd, Nippon Steel & Sumitomo Metal Corporation, Hitachi, Ltd., Furukawa Electric Co., Ltd., Shimizu Corporation and Mizuho Information & Research Institute. And, this project has been sponsored by the Ministry of Economy, Trade and Industry since March 2012.

In Fukushima FORWARD, JMU is in charge of EPCI (Engineering, Procurement, Construction and Installation) of floater part of the floating substation. The floating substation has been installed in fiscal 2013 summer.

In this paper, we describe characteristic features of floating substation. Then, we describe the unique method to construct and install the floating substation.

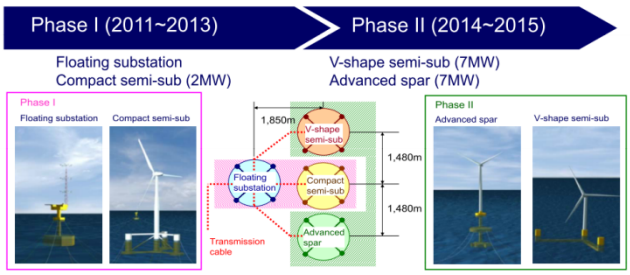

Fig. 1. Overview of Fukushima FORWARD

FLOATING SUBSTATION OF FUKUSHIMA FORWARD

The floating substation is a float designed to raise the voltage of the electricity generated by the offshore wind turbine and transmit the electricity to land. It is the world's first challenge to construct floating offshore electric power substation. Also equipped with instrument to observe meteorological phenomena, oceanographic phenomena, and float motion of the targeted ocean area, it also functions as an observatory obtaining data necessary for offshore wind farm.

In the electrical substation equipment part, a 25MVA transformer which raises the pressure of the 22kV electricity generated by the wind turbine to 66kV is installed. Hitachi Ltd. is responsible for the electrical substation equipment.

Moreover, underwater transmission lines are used for electrical transmission, connecting three 22kV lines and one 66kV line. Furukawa Electric Co., Ltd. is in charge of the transmission lines.

Principal particulars and main components of floating substation

At first, we show the outline isometric view of the floating substation in *Fig. 2*. And, principal particulars are shown in *Table 1*.

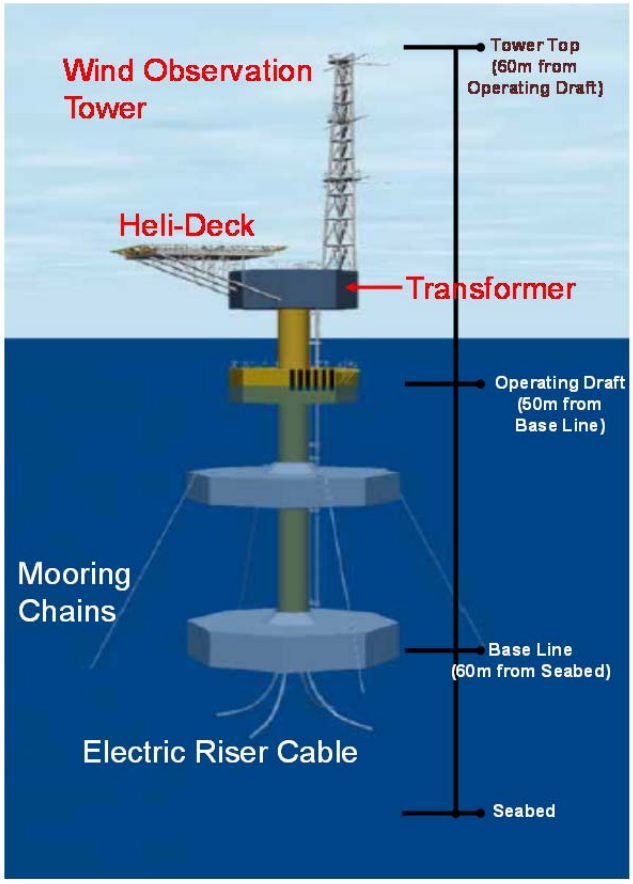

Fig. 2. Isometric view of floating substation

Table 1.Principal particulars of floating substation

Item	Value
Length (at middle hull)	33.4 m
Breadth (at middle hull)	33.4 m
Height (base line to tower top)	Abt. 110m
Draft (Operating)	50.0 m
Draft (Maintenance)	32.0 m
Displacement	Abt. 13,000 ton

The electrical substation equipment is located inside the upper hull which is at the top of the hull, a tower for observing wind conditions and helicopter deck for access in case of an emergency is provided. Also assuming an operation in time of a power failure, it is equipped with an auxiliary generator. The major equipments to be installed are listed below.

- 25 MVA Transformer
- Electric Rise Cable
- Observation Tower
- Observation Instruments (Doppler Rider, 3D Ultrasonic Anemometer, RTK-GPS etc.)
- Helideck
- Ballast Pump
- Axially Generator

The station keeping will be done with four mooring lines. The lines are composed by chains only and the nominal diameter is 132mm.

Design conditions

The location where Fukushima FORWARD will be conducted is a sea area 20km offshore from Fukushima Prefecture where the depth of water is approximately 100-120m. The yearly average wind speed in the sea area is more than 7.5m/s at 100m above water. *Tab. 2* shows the setting of meteorological and oceanographic conditions with 50 years return period.

In designing of the floating substation, Class NK Part P and some Code and Regulations (COLREG and MARPOL, etc.) were applied. Note, however that there are no crews, the classification society made significant allowances for the life saving and firefighting criteria.

The floating substation needs to satisfy the stability performance and low motion performance required by the electrical substation equipment and observation equipment that will be installed. So we adopt “Advanced Spar Concept” which had been developed by JMU from 2009 [2].

Also, as the riser cable has a limited range that it can follow, in the same way as rigs connected with drilling risers and offshore structures for production connected with flexible risers, there is a need to design mooring lines so as it will not be pushed outside of the certain range by environmental external force.

Table 2.Design conditions for Fukushima FORWARD (Return period = 50 years)

Wind Velocity (10min, @10m)	41.8 m/s
Significant Wave Height	11.7 m
Significant Wave Period	13.0 s
Current Velocity	1.5 m/s
Water Depth	100 - 120 m

CONSTRUCTION AND INSTALLATION

We show the construction and installation flow diagram for the floating substation in *Fig. 3*. In this section, we describe about the method to construct and install.

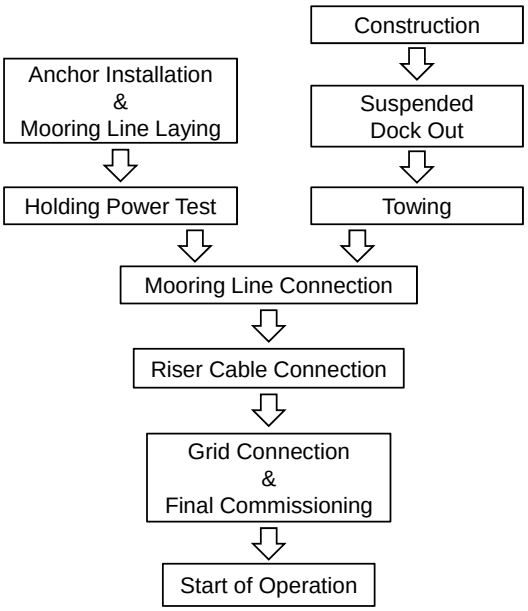

Fig. 3. Construction and installation flow diagram.

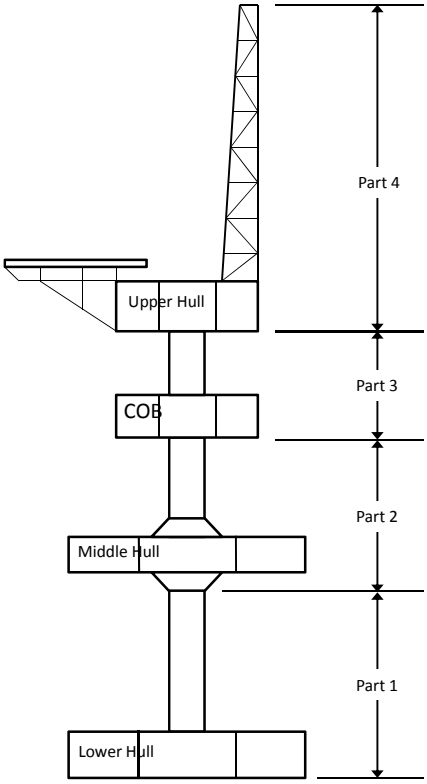

Fig. 4. Block division of floating substation.

Construction and dock out

The floating substation was constructed at JMU Yokohama Shipyard Isogo Works from December 2012 to July 2013. To begin with, the upper hull, the COB hull, the middle hull and the lower hull were separately constructed, and were constructed by composing the hull in order. The block division is shown in *Fig.4*. At last, “Mega block” composed by upper hull, COB hull and middle hull was installed on the lower hull part (Part1 in *Fig. 4*). The installation of mega block is shown in *Fig.5*.

After the erection, composed float was launched toward the installation site. Because the towing draft (32m) is deeper than the depth of dock (abt. 8m), the float was lifted and suspended by the floating crane and towed away from the dock (*Fig. 6*).

Installation

Before the towing of the float, mooring lines and anchors were installed beforehand and a test to see its holding power was conducted. The holding power test was conducted by pulling together the mooring lines on the opposite side on the barge. *Fig. 7* shows the deployment of the high holding drag embedded anchor.

Fig. 5. Mega block installation on lower hull part.

Fig. 6. Suspended dock out.

The towing, with the condition of towing draft (32m), was towed from Tokyo Bay going through Uraga Channel to the installation sea are in the offshore of Fukushima taking two days. The towing was done by one main tugboat and three assistant tugboats, navigating at the speed of approximately 4 knots. At the end of July, the float was connected to the previously installed mooring lines (*Fig. 8*) and electric riser cables.

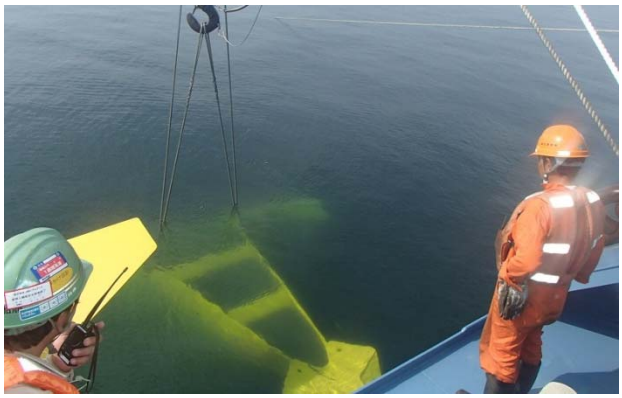

Fig. 7. Deploying the anchor.

Fig. 8. Installation of mooring lines

Fig. 9. Floating substation installed

Finally, the floating substation was installed at off the coast of Fukushima and started the operation as the world's first floating substation (*Fig. 9*) in 2013 summer.

ACKNOWLEDGEMENTS

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References

[1] Ministry of the Environment, *Study of potential for renewable energy introduction*, 2011.

[2] H. Yoshimoto et. al. , "Development of floating offshore substation and wind turbine for Fukushima FORWARD", *Proceedings of the International Symposium on Marine and Offshore Renewable Energy*, 2013.