Feasibility Study on Large Scale Offshore Wind Power off the Japanese Coast

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Abstract

Large scale offshore wind farms (OWF) are difficult to realize around Japanese coast because of its technological and economical reason due to their deep water, fishery issue and visual impact where are fishery area and national sea-parks almost everywhere. In order to investigate possibility of OWF in Japan, we made research of geological condition of the Japanese coast, and trial design of OWF. After these work, we made some proposal to realize OWF off the Japanese coast.

Approach

As basic policy,

1. Site of the OWF should be positioned at least off over 20 km from the shore (in exclusive economic water outside of territory) to avoid visual impacts and conflicts with fishery area.
2. OWF should be constructed near the large thermal power station to connect a strong grid.

We made a feasibility study on large scale OWF off the Japanese coast as follows,

1. Research of geological condition of the Japanese coast
2. Evaluation of wind turbine, especially its size and performance,
3. Trial Design of
   (1) Foundations of Jacket Type and two Tension Leg semi-submerged Floating Type which protect power transmission cable from excessive motion of the platform.
   (2) Electric Equipments, power transmission and total System for two scales of 100 and 1,000 MW OWF.
4. Expected power generation of OWF and Economical Evaluation when applied to actual field
5. Total system Evaluation

Research of geological condition for OWF off the Japanese seashore

As shown in Table1 and Fig.1, depth of the sea water at expected OWF position would be from about 50m to 100m and the scale of the OWF capacity from 100 MW to 1,000 MW if we take 20 % of the thermal plant capacity.]

Table^1　Candidate Place of OWD

No.	Candidate Power Plant	Power Plant	Capacity MWe	OWF Capacity MW	Depth (m) Distance 20km
1	Hachinohe	Thermal	500	100	80
2	Shi-Sendai	〃	950	200	40
3	Shinchi	〃	2,000	400	40
4	Haranomati	〃	2,000	400	60
5	Higashi-Niig	〃	2,909	600	100
6	Nakoso	〃	1,630	300	100
7	Hirono	〃	3,200	640	120
8	Kashima	〃	4,400	880	100
9	Shiga	Nuclear	540	100	150
10	Shimane	〃	1,280	250	100
11	Karatsu	〃	2,300	460	50

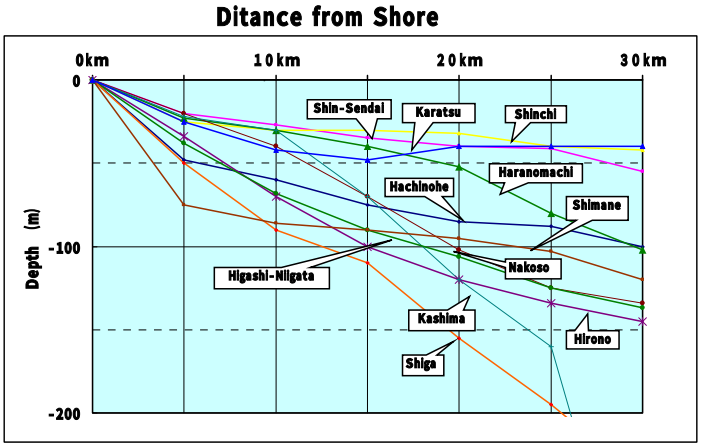


Fig.1　Depth of the sea expected OWF

Trial Designs and its results

Design Condition

1.Depth of the sea　;100m

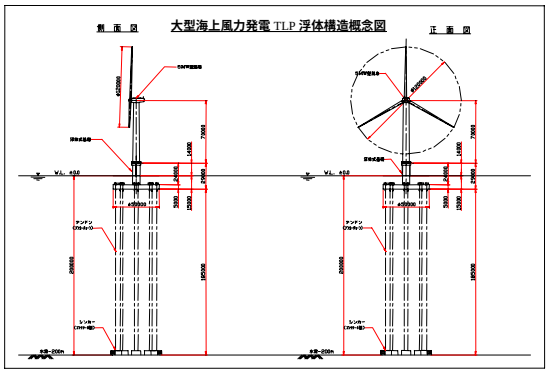
2.Turbine Capacity　;5 MW & 10 MW

3.OWF total output　;100 & 1,000 MW

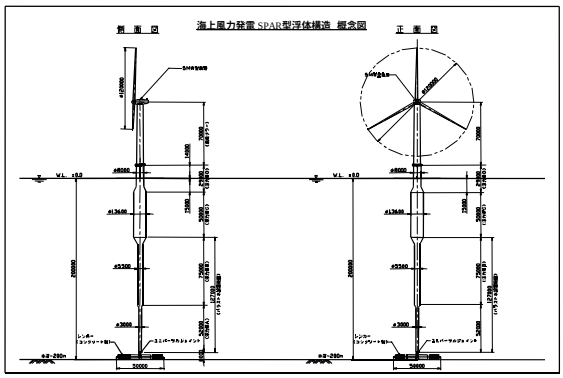
4.Foundation　　:Jacket type and submerged Tension leg Floating type

Foundation

Fig.2 shows that Jacket type is most suitable until 100 m Depth from economical viewpoint.



TLP semi-submerged floating type



Spur semi-submerged floating type

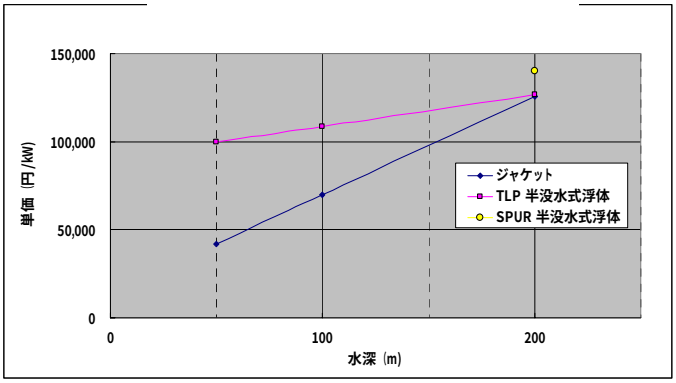


Fig2 Comparison of Construction Cost for Jacket type and Fixed Semi-submerged type

Conceptual Design of Large scale Offshore Wind Firm

1. 100 MW class OWF

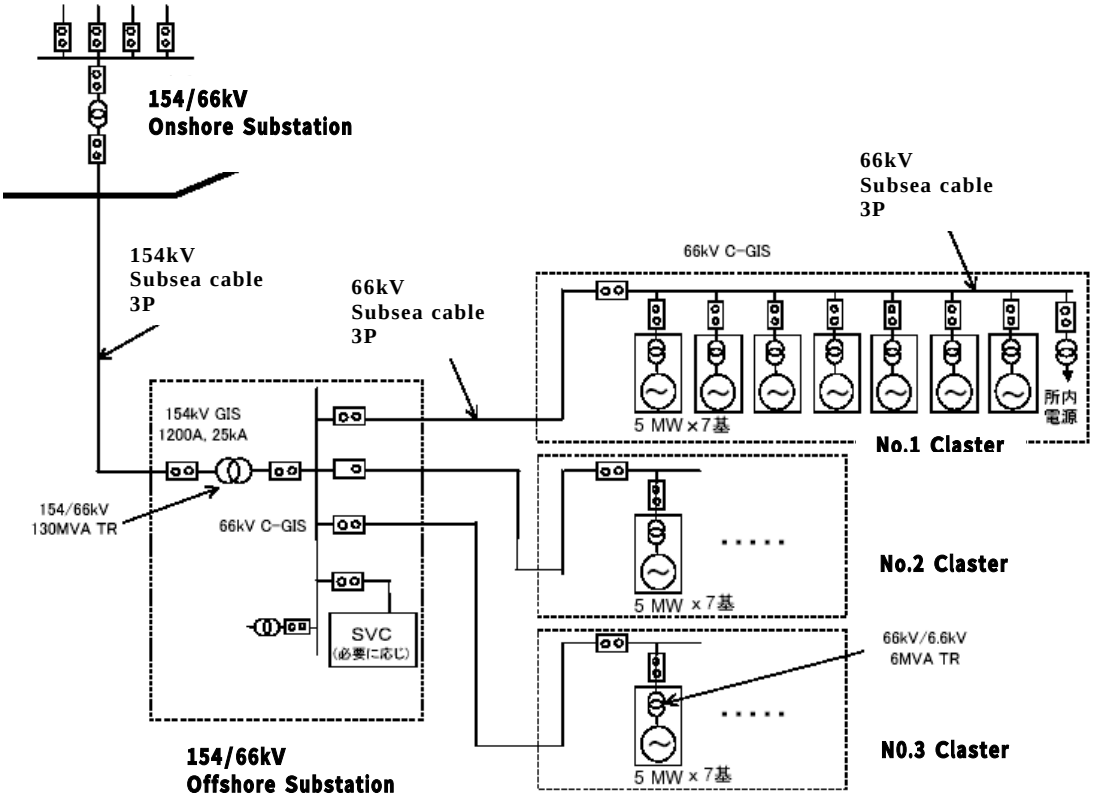
Design Condition

Unit ：105 MW (3 Cluster)

Cluster ： 35 MW (7 Turbine)

Turbine ： 5 MW

Electric Equipment and Power Transmission System



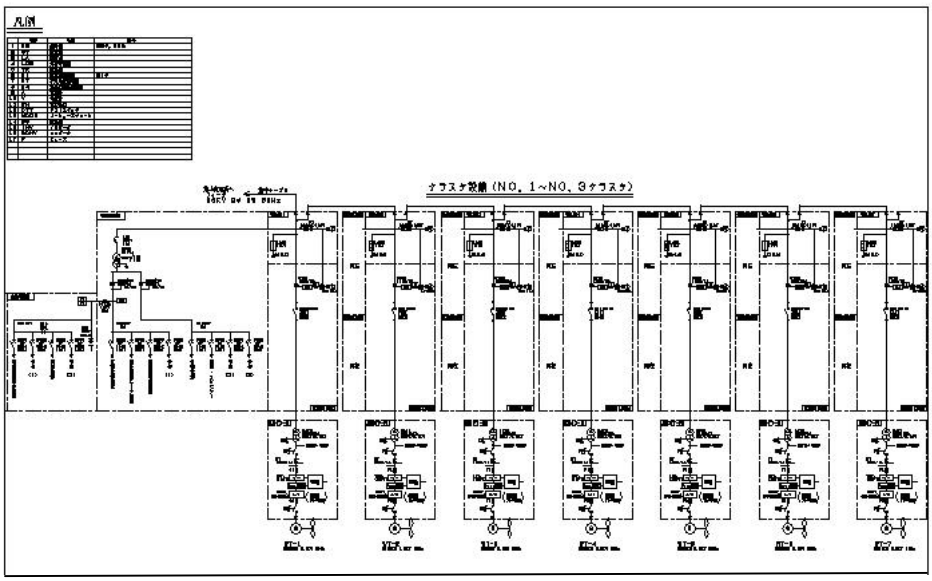
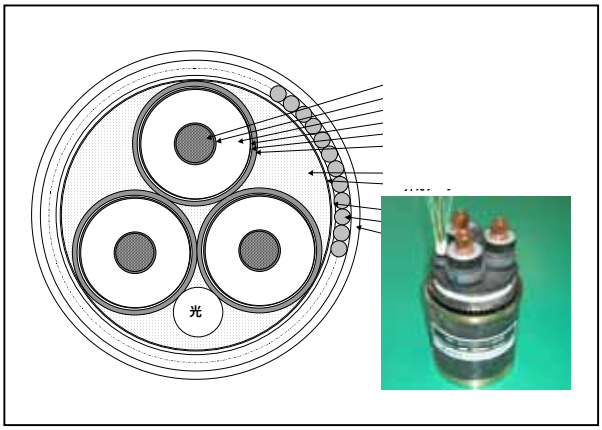


Fig.3 Single Line Diagram of 100 MW OWF offshore Substation

Submerged transmission Cable

There exist proven technoloies of Transmission cable for large capacity and high voltage up to 500 MV.



Submarine cable between on-shore and off-shore substation： OD 168 mm
Submarine cable between windmill and off-shore substation： OD 116 mm

Fig.4 AC transmission cable for 100MW class OWF

Construction Cost of Large scale OWF of 100MW class

We estimated construction cost of large scale OWF in Japan referring to data of Danish offshore wind firm (Horns rev. and Nysted OWF). As a result, in spite of deep sea in Japan, there are not so large differences of cost between them.

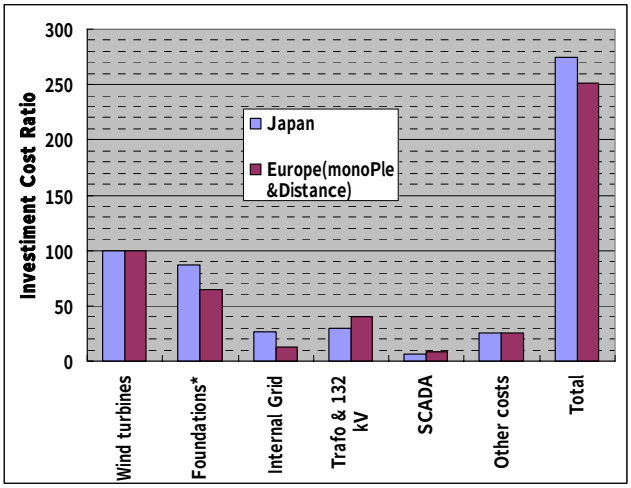


Fig.5 Construction Cost of 100MW OWF

Estimation of Generating Power

As we do not have data of Offshore Wind condition in Japan at present,, We adopted data of a on-shore coast at edge of peninsula which is thought near to off-shore one as shown in Fig.6.
As a result, The OWF plant will generate 300 GWHr per year for 100 MW plant and.its availability wll be 35% as shown in Table2

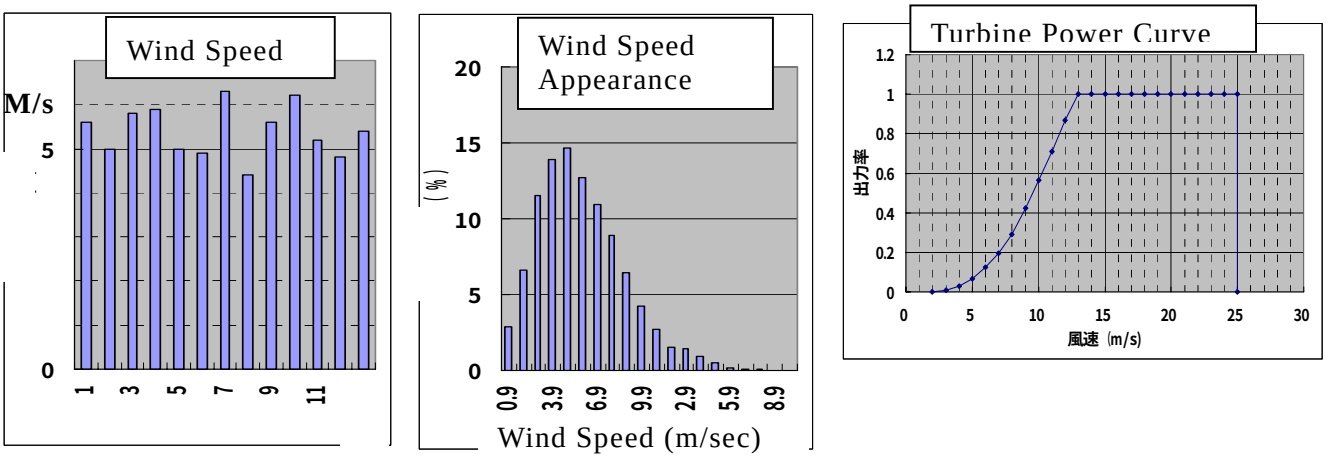


Fig.6 Wind Data at Kashima

Case	Capacity MW	Turbine	Ditance from Shore km	Wind Speed (m/s)	Generating Power (MWh)	Availability (%)
1	**100**	**2MW×50**	**20**	**7.5**	**278,293**	**31.8**
2	**100**	**5MW×20**	**20**	**7.9**	**307,152**	**35.1**

Table2 Estimated Wind Turbine Availability
in the case of Installing off Kashima shore
(used On-shore Data)

Evaluation of Economical Efficiency

Table3 shows economical evaluation using above results. In this calculation, standard value of of the plant availability is increased by 25% from the results of onshore. Standard construction cost is the integrated value above. As a result, electricity cost is 5 Yen/kWHr which is alittle higher than expected.

Table 3　Estimated Electricity cost for 100 MW class OWF

	unit	Pessimistic	Standard	Optimistic
Plant Capacity	MW	100	100	100
Plant Availability	—	35	42.5	50
Generating Power	MWHr	306,600	372,300	43,8000
Cost of Construction	Yen/kW	300,000	220,000	180,000
	MYen	30,000	22,000	18,000
Endurance Period	Year	20	20	20
O&M Ratio (%)	—	1.7	1.7	1.7
Estimated Electicity Cost	Yen/kWHr	8.3	5.0	3.5

2. 1,000 MW Class OWF

Design Condition

Unit　　：1000 MW (10 Clusters)

Cluster　　：　100 MW (10 Turbines)

Turbine　　：　 10 MW

Arrangement of Turbines off shore

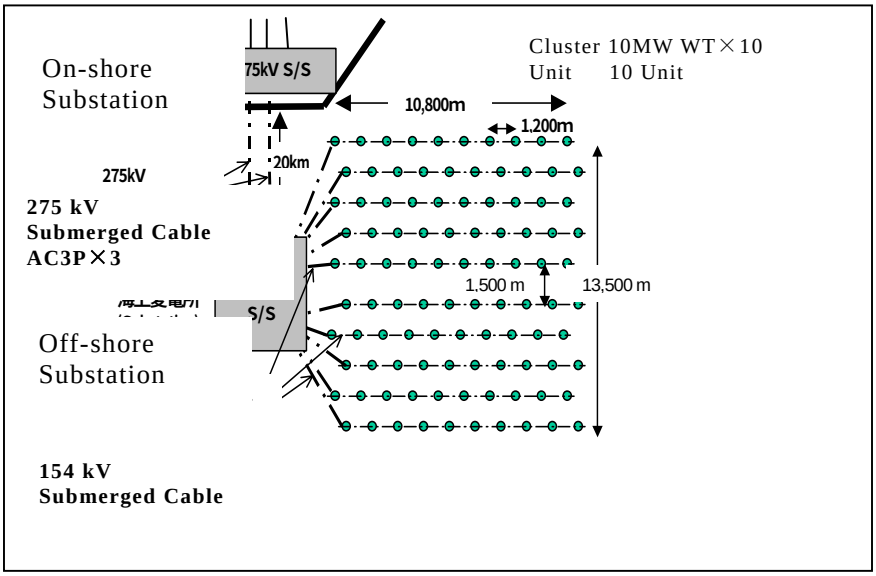


Fig.8　Arrangement of 1,000MW calss OWF

Conclusion

1. In order to construct large scale OWF off the Japanese coast, New technology of foundation for deep sea about 50～100 m depth is necessary. If it is possible, there are several positions suitable for construction of large scale OWF.
2. Cost of OWF construction at deep water is much lower than usually considered if we choose suitable technologies.
3. As for the type of foundation, Jacket type is more suitable than floating type until 100 m of depth of the sea area.

Feasibility

1. Feasibility

(1) Economy

Large scale OWF is economically constructed by the scale and multi-production effects. Electricity cost would be below 5 Yen per kW for 100 MW. However dramatic reduction of cost can be expected in larger scale of several hundred MW.

(2) Stability and Reliability

OWF should co-operate with a large scale thermal generating plant of several GW from grid stability viewpoint.

(3) Candidate position of OWF construction

There are good many candidate positions around Japanese coast.

Distance from the shore ：over 20 km

Depth ：50～100m

(4) Recommendation of Research and Development

Large scale Wind Turbine：10 MW class

Foundation for deep sea ：50～100 m, Bottom fixed (Jacket) type

Acknowledgement

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