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Research and development about the mechanisms of a single point mooring system for offshore wind turbines

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ABSTRACT

A new type of floating wind turbine, in which the floater itself can rotate from the wind is proposed in this paper. A new single point mooring system is necessary for the development of this new wind turbine. In this paper, the single point mooring system, which includes component such as catenary chains, the slip ring for the electric cable and the control cable were researched. This work will examine two different configurations of the single point mooring system that we developed. One uses a thrust bearing at the connecting points between the mooring parts and the floater parts. The other one uses not only a thrust bearing, but also an aligning bearing. Weather vane tests about the offshore wind turbine with each mooring system were conducted in an ocean basin. After performing wind tests of both configurations of the single point mooring system, it was concluded that the latter one functioned superior to the former one. This work discusses and clarifies the reason based on a physics model which focuses on the relation between the restoring yaw moment caused by the mooring chains and the static friction moment due to the bearing unit. We also performed a wind test at a real sea and verified that the bearing unit with not only the thrust bearing but also the aligning bearing could function properly.

1. Introduction

Utilizing ocean renewable energy is promising as an efficient energy resource in the future. Particularly, offshore wind energy is one of the most anticipated solutions. In Japan's case, we have a vast Exclusive Economic Zone (EEZ). New energy and industrial technology in Japan has estimated that the potential quality of wind power can reach from roughly 1500 million KW to 1600 million KW. Floating wind turbines (FWTs) can be used for this even if the sea depth is over 50 m. For this reason, FWTs are researched and developed all over the world. For example, the first full scale FWT is being tested off the shores of Norway (Hywind Demo, 2009). In the Hywind project, a 2.3 MW wind turbine is mounted on a spar type platform with four catenary chains. Another FWT project is being performed off the shores of Portugal (WindFloat, 2011). In that project, a 2.0 MW wind turbine is mounted on a three column semi-submersible. A 7 MW semi-submersible floating wind turbine, in which the tower of the turbine stands on one of the three columns of the semi-submersible similar to WindFloat was recently manufactured by Mitsubishi Heavy Industry(MHI). (http://www.fukushima-forward.jp/english/). MHI's FWT was installed near the shores of Fukushima, Japan and as of 2016, is currently being tested for power functionality and it's cost efficiency performance is also being measured as well. Many other projects like these are also being conducted all over the world (GOTO FOWT, 2013; DeepCwind Consortium, 2013).

We would like to mention some technical problems here regarding offshore wind turbines. In the case of horizontal wind turbines, blades, a rotor, a blade pitch control motor, a shaft, a gear box, a generator, a yaw control unit, and many other mechanical components are located on the top of the tower. This top heavy state leads to the floater being

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Table 1
Principal particulars of the wind turbine (values are in scale).

Item	Unit	Value
Diameter of the rotor	m	2.4
Length of the tower	m	1.65
Tower mass	kg	8.95
Nacelle mass	kg	2.5
Generator mass	kg	8.4
Power output	W	700

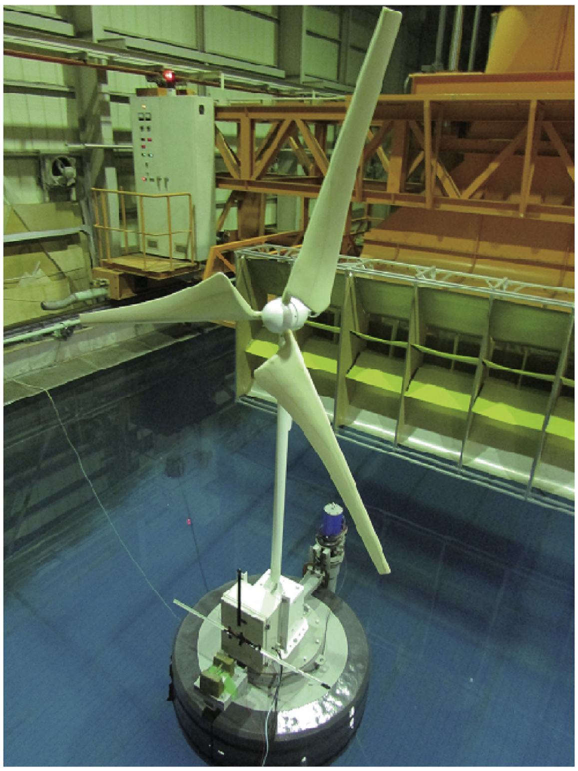

Fig. 1. Photo of the floating offshore wind turbine.

heavier and bigger. It is better for some mechanical parts to be set below the tower. In addition, when an electricity-based accident occurs in severe weather conditions, the yaw control gear or the pitch control gear will not function. In the case of trouble with the yaw control gear, the wind turbine will fail to move properly based on the direction of the wind, causing potential blade damage due to the lack of control if the wind conditions are too harsh. Pitch control motor failure is also a problem for the horizontal wind turbines (Faulstich et al., 2011). This motor failure leads to heavy bending at the base of the tower due to too much thrust force. Damage to the tower as a result of this heavy bending has been reported (The accident investigation committee of Wind Park Kasatori Power Plant, 2013; Mizukami et al., 2016).

Our new concept for a floating wind turbine adopts the single point mooring system. The first small model test which used a 1/100 model of the 5 MW wind turbine with a stainless wire as its mooring cable was

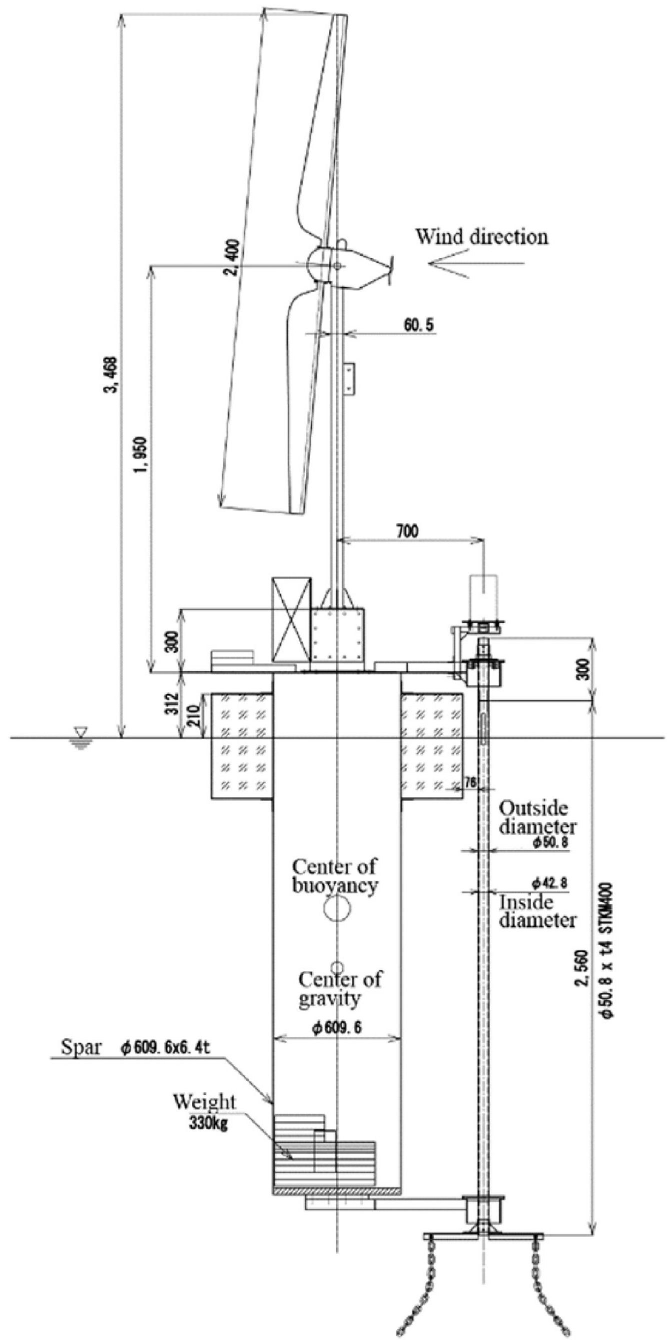

Fig. 2. Floating offshore wind turbine model.

Table 2
Principal particulars of the platform (values are in scale).

Item	Unit	Value
Diameter of the floater	m	1.2
Length of the floater	m	0.5
Diameter of the platform	m	0.609
Length of the platform	m	2.78
Platform mass	kg	850
Ballast mass	kg	330
Draft(FWT)	m	2.375
KG(FWT)	m	1.24
KB(FWT)	m	0.16
GM(FWT)	m	0.54
Mooring lines	–	3
Method of mooring	Catenary	–