The effect of the number of columns on the platform stability

Ho-Seong Yang* and Young-Ho Lee**
*Department of Mechanical Engineering, Korea Maritime and Ocean University
727 Taejong-ro, Yeongdo-gu, Busan, Republic of Korea
E-mail: kpsc1908@g.kmou.ac.kr
**Division of Mechanical Engineering, Korea Maritime and Ocean University
727 Taejong-ro, Yeongdo-gu, Busan, Republic of Korea

Abstract

This paper aims to enable stable platform design by analyzing the effect of the number of columns constituting the platform on the system movement. Since the economic feasibility of a wind power generator greatly depends on the size of wind energy, it is very important to select a suitable site for high-wind conditions. Marine environment data such as wind speed, wind direction, wave height, wave period, and current required for analysis were obtained through the national meteorological observation equipment installed near the site. The platform type is selected with a semi-submersible structure and the turbine is installed with IEA-15MW. The number of columns consisting platform is designed three columns to six columns by increasing one by one. The total mass of the designed FOWTs(floating offshore wind turbine systems) and other structure design variables are fixed. But when increasing the number of column, to fix the total mass, some minor structure design variables that not too much big effect to the system behavior are changed. To analysis of the column effect, using the OrcaFlex, a potential-flow-based analysis code simulation program. Fully-coupled simulations are performed. The tower, Rotor-Nacelle Assembly part (RNA), and mooring line were combined on the designed platform under the operating wind speed condition.

Keywords : 15MW wind turbine, Floating offshore wind turbine system, Fully-coupled simulation, Semi-submersible, Column

1. Introduction

There are many various factors such as draft, column radius, and spacing between columns when the FOWT platform design. Some researchers were performed design parameter sensitivity analysis of various design variables including the above-mentioned design variables for a FOWT consisting of four columns of a type that installs a superstructure at the center of a platform. It was confirmed that it had a great influence on the behavior of the platform and the natural frequency value (Zhou et al, 2021). In this paper, considering more efficient the super large-size turbine installation, the platform that the tower, nacelle and blade are installed on the side main column are deigned. The purpose of this paper is to determine the optimal number of columns by analyzing the natural frequency value and behavioral characteristics determined by the number of columns that have a dominant influence on platform optimization.

2. Method

The platform design was performed in two ways. First of all, the platform was designed by increasing the number of columns one by one from 3 to 6 in common for both methods. In the first method, the number of columns was simply changed while keeping the design parameters such as the column radius, and column thickness. In the second method, the number of columns was increased while maintaining the total material mass used in platform and minor structure design variables such as column thickness were adjusted. In order to analyze the platform motion characteristics according to the number of columns, an IEA-15 ㎿ turbine was mounted on the platform and the tower is used by applying the turbine in this study were applied (Allen et al, 2020). And for the reference total platform mass, which is essential for the design of the platform, the Umaine VolturnUS-S hull steel mass used for the platform was applied. When designing the platform, the shape of the platform was designed according to the number of columns by selecting the type

in which the upper structure suitable for enlargement was installed on the side. The study selected a virtual installation site, collected met-ocean data such as wind and wave currents at the location, and analyzed the kinetic characteristics of the designed FOWT by selecting a design load case. OrcaFlex simulation program capable of analysis was used.

3. Results

Simulations were performed for a total of 630 cases, taking into consideration various wind conditions and waves with irregular wave. The wind condition set at intervals of 2 m/s from 3 m/s to 21 m/s. All six degrees of freedom of the system and the nacelle acceleration affecting the turbine performance were analyzed, but only the system pitch motion and tower bending moment, which clearly showed a difference in values depending on the number of columns, were shown. Fig. 1 shows the pitch motion and the average amplitude of the pitch that averaged all the results of the time domain for 600 seconds for each column. From these result, we can know that the pitch motion is more stable increasing the number of column. In Fig. 2, the moment applied to the bottom of the tower according to the number of columns was confirmed. It was found that the bending moment had no significant correlation with the number of columns, but the amplitude at which the tower bending moment occurred in the time domain decreased as the number of columns increased. Confirmed. Fig. 3 shows the pitch motion results of the system with the same weight used in the platform designed in the second design method. As the number of columns increases, the pitch motion is stabilized as in the pitch motion results of the first design method. Fig. 4 is a graph showing the bending moment applied to the lower part of the tower according to the number of columns of the platform designed in the second design method. It can be seen that the moment applied to the lower part of the tower decreases as the number of columns increases.

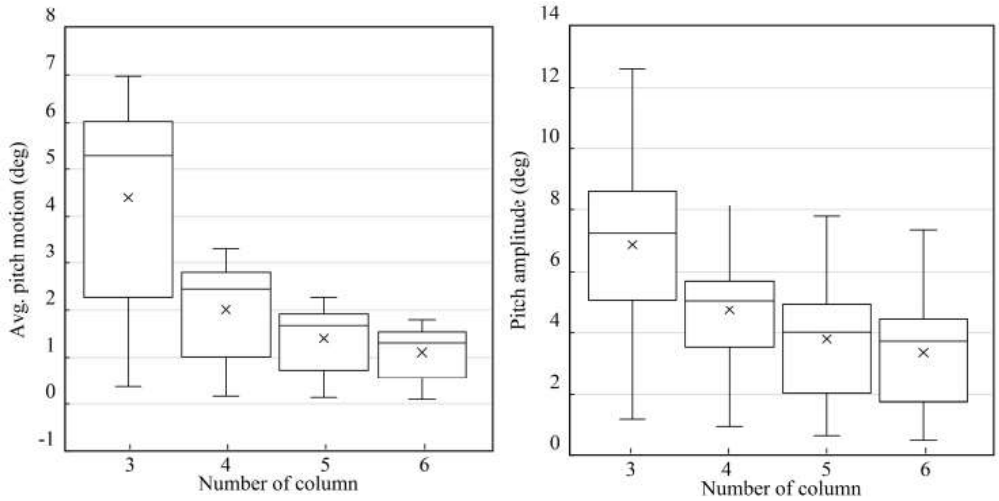

Fig. 1 FOWT average pitch position and pitch amplitude simulation result depend on the number of column

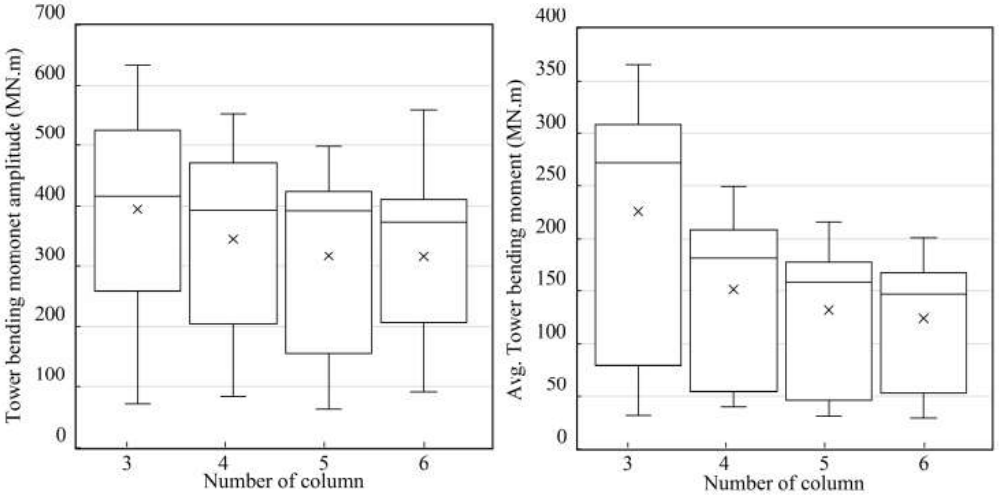

Fig. 2 FOWT average Tower bending moment value and moment value amplitude simulation result depend on the number of column

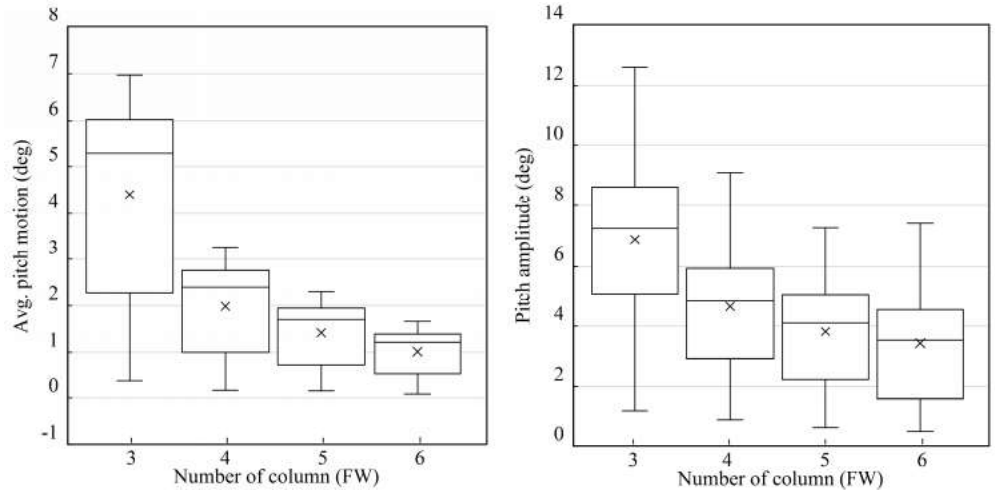

Fig. 3 (FW)FOWT average pitch position and pitch amplitude simulation result depend on the number of column

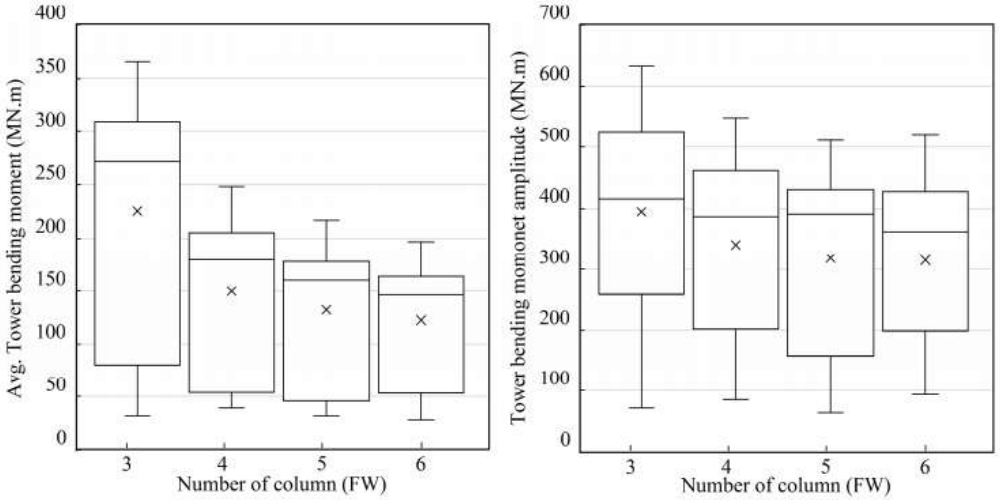

Fig. 4 (FW)FOWT average Tower bending moment value and moment value amplitude simulation result depend on the number of column

4. Conclusion

In this study, the behavior characteristics of the platform according to the number of columns, which have a dominant influence on optimization, are used in platform design. Through the fully-coupled simulation results, the following results were derived for the FOWT system according to the number of columns.

- As the number of columns constituting the substructure of the FOWT increases, the pitch movement is more stable.
- As the number of columns increases, the load on the lower part of the tower decreases.

When designing the platform, it is important to consider the environmental conditions of the sea area where the floating wind turbine is installed. The environmental conditions carried out in this study only considered the situation in which the environmental load was applied in the direction of the turbine. Therefore, there was a limit in understanding the correlation with the number of columns for yaw, sway, and roll movements. In addition, since the wave height in the corresponding environmental condition was not high, it was difficult to understand the correlation between the heave movement and the number of columns. Therefore, it is judged that it is necessary to add and analyze the wave spectrum considering the environmental load and high significant wave height in various directions in order to understand the clear correlation with the number of columns for the corresponding movements.

References

Z. Zhao, W. Shi, W. Wang, S. Qi, and X. Li, “Dynamic analysis of a novel semi-submersible platform for a 10 MW wind turbine in intermediate water depth”, Ocean Engineering, Vol.237, 2021

C. Allen, A. Viscelli, H. Dagher, A. Goupee, E. Gaetner, N. Abbas, M.Hall, and G. Bartonr, Definition of the UMaine VolturnUS-S Reference Platform Developed for the IEA Wind 15-Megawatt Offshore Reference Wind Turbine, Golden : National Renewable Energy Laboratory(NREL), 2020.