The Dynamic Coupling Effects of a MUFOWT (Multiple Unit Floating Offshore Wind Turbine) with Partially Broken Blade

Y.H. Bae*, M.H. Kim**, Q. Yu***
* Department of Ocean System Engineering, Jeju National University
  Jeju-si, Jeju-do, Korea
** Department of Civil Engineering, Texas A&M University
  College Station, TX, USA
*** American Bureau of Shipping
  Houston, TX, USA

ABSTRACT

Recently, several numerical simulation tools for the analysis of a Floating Offshore Wind Turbines (FOWT) have been developed by many research institutes. Most of the existing numerical tools can analyze only a single turbine with a floating platform. In this study, an advanced numerical simulation tool has been developed for the rotor-tether coupled dynamic analysis of Multiple Unit Floating Offshore Wind Turbine (MUFOWT) in the time domain including aero-blade-multiple tower dynamics and control, mooring dynamics and platform motion. In particular, the developed numerical tool is designed based on the single turbine analysis tool FAST, which has been developed by National Renewable Energy Laboratory (NREL) for years. For linear or nonlinear hydrodynamics of floating platform and generalized-coordinate-based FEM mooring line dynamics, CHARM3D is incorporated. So, the entire dynamic behavior of a floating offshore wind turbine can be obtained by coupled FAST-CHARM3D in the time domain. To analyze the dynamics of multiple turbines on a single platform, the coupled FAST-CHARM3D is further expanded and re-constructed. The global coefficient matrix that includes one floating platform and a number of turbines is built at each time step of the simulation, and solved simultaneously to obtain the responses of the entire degrees of freedom of the MUFOWT system. To investigate the dynamic coupling effect between platform and turbines, a five-turbine semisubmersible is modeled and simulated. To check the dynamic coupling effect, extra 1P excitation from one turbine by partially broken blade is intentionally generated and the transferred loads to the platform and the other turbines are measured. The analysis shows that the dynamic load imbalance of one turbine in MUFOWT may induce significant changes in the performance of the other turbines or a floating platform.

KEY WORDS:  Renewable Wind Energy, Offshore floating wind turbine, MUFOWT (Multiple Unit Floating Offshore Wind Turbine), multiple turbines, semi-submersible, aero-elastic-control-floater-mooring coupled dynamics, partially broken blade, health monitoring, wind farm.

INTRODUCTION

It is widely accepted that the cost increase of FOWT is not very sensitive to the increase of floater size. In this regard, another interesting and plausible FOWT concept named MUFOWT (Multiple Unit Floating Offshore Wind Turbine) is proposed. This model includes multiple wind turbines on a single floating platform rather than the typical concept of one wind turbine on one floater. The possible advantages and disadvantages of a MUFOWT over a single-unit floating turbine were discussed (Barltrop, 1993; Jamieson and Bramney, 2012) and an effort was made (Henderson et al., 1999) to develop simplified analytical tools for evaluating the performance of the multiple-turbine floater.

Compared to the single-unit floating wind turbine, MUFOWT has several advantages. First, many turbines can share the floating base and mooring lines to minimize respective costs. The entire unit can be fabricated at the quay side and towed to connect to a pre-installed mooring system. This way installation cost can be minimized. From a stability point of view, MUFOWT generally provides a more stable condition than a single-unit floater, since the platform size is much greater than single unit floater. The increased stability also enables higher towers and larger blades for higher energy capture. In random sea environments, better response characteristics are expected because larger floating units usually tend to have less response. A larger floating platform may be equipped with a helicopter port for access by air.

On the other hand, there are also several disadvantages of the MUFOWT concept. One of the most serious problems is the possible interference among turbines when one unit fails to operate normally. Another anticipated problem is the possibility of a performance drop caused by the blade shade effect due to insufficient distance between them. This disadvantage may be overcome by adopting an ingenious floater design or turbine arrangement. In the earlier research of MUFOWT, such a large floating structure with multiple turbines was not regarded as cost-effective. However, recent technological developments and use of bigger turbines make this concept more viable.

In this regard, a fully coupled dynamic analysis computer program including multiple turbines on a single floater and mooring lines is developed by combining and expanding several computer-aided engineering (CAE) tools. Initially, for the dynamic analysis and control