Multi-Criteria-Decision-Making of a TLP Support with Large-capacity OWT at Deep Water

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ABSTRACT

The paper presents an optimization methodology for comprehensive evaluation of a TLP support with multi-megawatt OWT. Design optimization based on principle dynamic properties of a TLP support system is performed, taking consideration of both resonances of rotational excitation frequency of the OWT and the second-order sum-frequency wave excitations. Reasonable engineering attributes verified by performances of the structure are derived with depth variation. The attributes of TLP support are applied in multi-criteria decision making method-TOPSIS for benchmarking of those feasibilities. The results illustrate the effectiveness of proposed methodology in MCDM combining with economical and environmental attributes together.

KEY WORDS: Offshore wind turbines (OWT); Tension leg platform (TLP); Multi-criteria decision making (MCDM); Optimization technique; dynamic property; Technique for order preference by similarity to ideal solution (TOPSIS) method

INTRODUCTION

Wind energy industry has moved interest offshore, taking advantage of relatively unrestricted space, lower social impact and richer wind resource. A considerable number of OWTs have been installed in Europe, especially in such countries as Denmark, Sweden, England and Germany etc. Reference shows offshore wind power will cover 14% of EU’s electricity demand by 2030 (Arapogianni A, 2012). Interest in offshore wind energy is growing in U.S. and several projects are reaching design stage (Mark JK et al, 2013). Meanwhile, China shows consistent potential for development of offshore wind energy and some provinces initialized investigation for offshore wind farms.

The main projects of OWT in the past were in shallow water utilizing monopile, tripod, lattice foundations fixed on seabed (Zaaijer MB, 2006). To date, most existing OWT technology deployments are limited to water depths of 40 meters, while the wind at a deep-water location is typically more consistent and stronger due to the absence of topographic features that disrupt wind flow. For worldwide deep-water wind resources are extremely abundant in subsea areas with depths up to 600 meters, which are thought to best facilitate transmission of the generated electric power to shore communities. Increasing efforts are being made for developments at deeper sites where bottom-mounted towers are not feasible, a floating wind turbine – a wind turbine mounted on a floating structure is developed to offer an alternative to fixed foundations starting from 50m water depth (Tong KC, 1998).

A range of floater concepts are considered in deep water wind farms, including the most common forms conventionally used in oil and gas industry (such as barge, Spar and TLP) (Lefebvre S et al, 2012) (Karimirad M et al, 2011). Among them, TLP is a floating platform that achieves stability by exploiting a tensioned mooring system by high tensioned lines anchored to the sea bed. Typical control strategies of land based turbine can directly be applicable to TLP-type support systems without any significant modification due to their limited vertical plane motions (Bachynski EE et al, 2012). Modern Mini-TLP would be an ideal solution for offshore wind farm because large platform area is unnecessary here. However, unlike other floaters, it cannot avoid the second-order sum-frequency wave excitations, which will cause such resonant vertical plane motions unless damping is large and consequently increase tethers’ tension (Bae YH et al, 2013) (Roald L., et al, 2013).

Research on floating support structures of OWTs is only at early stage comparing with conventional offshore structures. Design processes so far have been based on the experience coming from both wind turbine designers and offshore structure designers. For landed wind farms, rotor-nacelle assemblies and towers are mass produced assuming foundation as fix ends, while it would be sound to take foundation and tower as an integral supporting system subjected to aerodynamic and mechanical loadings from OWT and hydrodynamic marine loadings simultaneously. Besides, the critical requirement of avoiding resonance at turbine rotation frequency and second-order sum-frequency wave excitation restricts optimization process of support structures.

Increasing size of wind turbines and deep water exploitation are feasible ways to make offshore wind energy cost competitive, while it will result in huge initial investment for offshore installation is highly sensitive to the weight of components. It is an essential requirement to make support structures of OWTs economic through effective optimization at early design phase (Pedro SV et al, 2014). In view of the