Performance of Tuned Mass Dampers for Vibration Reduction in a TLP Floating Wind Turbine

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ABSTRACT

Tension leg platform (TLP) floating wind turbines (FWTs) experience high-amplitude, dynamic structural vibrations under complex loading conditions. Tuned mass dampers (TMDs) are a simple yet effective means to reduce such loadings. This work focuses on load reduction by TMDs for the WindStar TLP system, and optimizes the TMDs' parameters in a parametric study. Dynamic analysis then assesses FWTs with and without a TMD in a selected set of load cases. Results show that optimized TMD can reduce nacelle acceleration by up to 20%, especially in extreme conditions.

KEY WORDS: Floating wind turbine (FWT); tension leg platform; structural vibration control; tuned mass damper (TMD).

INTRODUCTION

Wind power is a promising form of renewable energy, and many countries are developing it as a replacement for traditional energy sources. Commercial wind farms are currently mostly located on land using fixed-bottom wind turbines. However, locating a wind farm offshore could harness wind speeds that are, on average, 90% greater than those on land (Archer and Jacobson, 2005). The gradual shifting of global wind energy exploitation offshore (Kaldellis and Kapsali, 2013) can encounter problems such as wave and ice loading, more-expensive foundations, and higher operation and maintenance costs (Stewart and Lackner, 2013). Among these, the massive vibration responses due to the combined environmental and working loads can lead to serious structural safety problems. Therefore, load reduction is extremely important for offshore wind turbines, as it allows increased reliability and possibly safety problems. Therefore, load reduction is extremely important for offshore wind turbines. TLPs suffer this vibration problem. For a TLP platform, the vertical stiffness is significantly higher than that for other floating platforms, so we should consider both lower and higher modes of vibration (Butterfield, Musial, Jonkman, and Sclavounos, 2007).

Considerable recent attention has been paid to the research and development of structural control devices. Friction dampers have been applied in various structural contexts, both new and retrofitted, to enhance seismic protection (Soong and Spencer, 2002). They can be applied to wind turbines to protect the structure from dynamic loads due to waves, wind, and earthquakes.

Structural control can be passive or active. Passive systems use a range of materials and devices to enhance structural damping, stiffness, and strength. Active systems, which include active, hybrid, and semi-active systems, employ controllable force devices integrated with sensors, controllers, and real-time information processing (Soong and Spencer, 2002).

The application of structural control techniques to wind turbines is a relatively new area of research (Lackner and Rotea, 2011). The complicated loads encountered at sea require any structural control device for FWTs to be reliable, simple, and efficient during the turbine’s lifecycle. Passive control devices are simpler than active ones, and require no power to operate. As the platform vibrates, some of the vibrational energy is transferred to the mass of the structural control device and dissipated by the damper (Stewart and Lackner, 2013).

Musial, Butterfield, and Ram (2006) established a three degrees of freedom (DOF) dynamic model for different types of floating wind turbines, and designed tuned mass damper (TMD) parameters by different optimization methods. This limited-DOF model can provide simple and efficient optimization and active control design, but it...