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Inerter-based dampers for vibration control of floating offshore wind turbines

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Abstract: This paper analyses the performance of tuned mass damper inerters (TMDI) for vibration control of spar-type floating offshore wind turbine towers. The use of an inerter in parallel with the spring and damper of a tuned mass damper (TMD) is a relatively new concept. The ideal inerter has a mass amplification effect on the classical TMD leading to greater vibration control capabilities. In this work we compare an "ideal" TMDI that assumes the use of a mechanical flywheel type inerter, with a "realist" fluid inerter. The fluid inerter is rather simple in design and it comes with very low maintenance. Numerical results demonstrate impressive vibration control capabilities of inerter-based dampers under various stochastic wind-wave loads. It has been shown that the fluid-inerter performs as well as the ideal mechanical inerter. The practical advantages of a fluid-inerter over the standard mechanical inerter makes it an exciting candidate for vibration control in offshore wind turbines.

Keywords: Inerter, Tuned mass damper, stochastic wind-wave loads, wind turbine, floating offshore wind turbine.

1. Introduction

The future of wind energy lies offshore. The cost of offshore wind turbine foundations is about 45% of the wind turbine cost in shallow water depths [1]. The concept of floating offshore wind turbines (FOWTs) was proposed to address the cost issue as turbines are installed in increasingly deeper waters. FOWTs have been realised in recent years in offshore wind farms in Scotland (Hywind) and Portugal (WindFloat). FOWTs present additional challenges to traditional onshore or fixed base offshore turbines. FOWTs are very large flexible structures installed in very harsh environments. These structures are subjected to turbulent aerodynamic and hydrodynamic loads and are constantly rotating. Mitigating the structural vibrations of FOWTs is now a very active area of research since vibrations of the blades and towers of FOWTs will affect the power production [2] and will also affect the reliability of the structures [3]. There have been many different vibration control schemes proposed to reduce vibrations in offshore wind turbines. Passive control via tuned mass dampers has been proposed by researchers and is now standard in the industry for multi-megawatt offshore wind turbines. Some wind turbine vibration control studies have made use of recent developments in damper design due to the emergence of the so-called 'inerter'. Inerter-based dampers can provide a mass amplification effect which increases the effective mass of the device, thus improving its vibration control performance. Inerter-based dampers have been considered for vibration control of floating offshore wind turbines [4-5], however, all the inerter-based dampers investigated to date in the wind turbine literature have made use of "ideal" mechanical inerters, realised via gearing systems, rack and pinion assemblies, or other mechanical components. In this paper, we propose the use of a tuned mass damper fluid-inerter (TMDFI) for vibration control of a spar-type floating offshore wind turbine towers. We compare an “ideal” TMDI that assumes the use of a mechanical flywheel type inerter, with a “realist” fluid inerter.

2. Results and Discussion

We have developed a high-fidelity multi-body dynamic model of the FOWT coupled with a TMDFI using Kane's method for numerical investigation in the paper – details to be provided in the full paper. Fig. 1. shows the damper details and a schematic for the installation inside the tower.

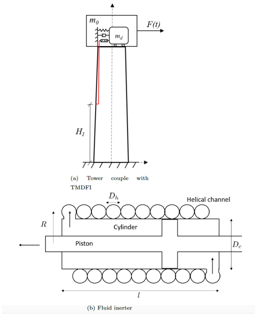

Fig. 1. Schematic of FOWT with TMDFI details

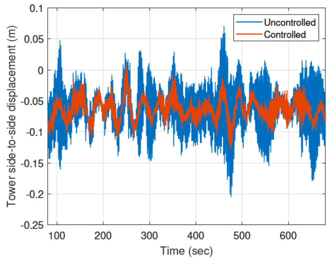

Fig. 2. Load Case 1.1: Tower side-to-side displacement

We have shown that the TMDFI has excellent vibration control performance across a wide envelope of met-ocean conditions and load cases. A typical time-history response is shown in Fig. 2, thr vibration control achieved is impressive. The TMDFI performance is as good as the “ideal” TMDI. This is particularly encouraging since the design and maintenance of a fluid inerter is simpler and cheaper than an “ideal” mechanical inerter. Details will be provided in the full paper.

3. Concluding Remarks

The TMDFI offers great potential in vibration mitigation for floating offshore wind turbine towers. This damper performs significantly better than a classical TMD and comparable to an “ideal” mechanical inerter. The extended version of this manuscript will include details on the modelling, design and optimization of the TMDFI. Greater details will also be provided on the environmental loading and the FOWT multi-body dynamic model.

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