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Wave- and Wind-induced Responses of the Semisubmersible Wind Energy and Flap-type Wave Energy Converter Based on Experiments

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This paper presents a study of the wave- and wind-induced responses of the combined energy concept Semisubmersible wind energy and Flap-type wave energy Converter (SFC) under operational and survival conditions based on experimental data. The measured responses that are studied include the motions of the semisubmersible, the rotation of the flap-type Wave Energy Converters (WECs), the tension of the mooring lines, the internal loads in the arms of the WECs, the bending moment at the base of the wind turbine tower, and the produced power by the WECs. The effects of both the change of the mean heeling angle of the SFC and the aerodynamic damping are studied. In consideration of a constant and uniform wind field, the effect of the wind loading on the structural responses of different parts of the WECs of the SFC is small.

INTRODUCTION

The technology in the offshore renewable energy sector that can be considered mature enough is the Offshore Wind Turbine (OWT) technology. The Levelised Cost Of Energy (LCOE) of OWTs in 2013 was in the range of 130 to 330 USD/MWh (World Energy Council, 2013). The cost of OWTs is the main handicap for their further utilization. In order to reduce the cost of generated power, the development of large wind turbines with high rated power in deep seas is considered to be an efficient potential solution. For deep seas the use of Floating OWTs (FOWTs) is considered to be the most cost-efficient solution. Different floating support platform configurations are possible for use with FOWTs (Jonkman and Matha, 2011). A major type of support configuration is the semisubmersible platform consisting of three columns that are connected through the use of braces (Roddier et. al., 2010). Alternatively, the columns of the semisubmersible platform can be connected by pontoons with large dimensions without braces (Olsen, 2015; Karimirad and Michailides, 2015). Three-column braceless semisubmersibles have been deployed in the past in the offshore oil industry; the results, which are based on physical model tests and full-scale tests accounting for free surface and water depth effects, are comprehensively examined by Chung (1976, 1994).

Ocean waves are an extremely abundant and promising resource for alternative and clean energy. Many different types of Wave Energy Converters (WECs) have been proposed. The first patent for a WEC was registered in 1799 in France by Monsieur Girard and his son (Michailides, 2015). Unfortunately, the technology of WECs cannot be considered mature enough for large-scale commercial deployment. The LCOE of WECs in 2013 was in the range of 280 to 1,000 USD/MWh (World Energy Council, 2013). WECs can be deployed in multi-purpose floating structures (Michailides and Angelides, 2015).

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It might be beneficial to combine offshore renewable energy systems with different technologies into one floating platform. The possible advantages of the use of offshore combined concepts are as follows: (a) an increase of the energy production per unit area of space; (b) a decrease of the cost per MWh production of energy of a pure OWT or a pure WEC; (c) a decrease of the cost related to the required electric grid infrastructure; and (d) a decrease of the cost related to operation (e.g., installation) and maintenance (e.g., inspection). Recently, European Union (EU) research projects have been introduced to accelerate the development of offshore combined energy systems.

In the EU project MARINA Platform (2015) three combined concepts have been selected and studied both numerically and experimentally. These three combined concepts are the Semisubmersible wind energy and Flap-type wave energy Converter (SFC) (Michailides et al., 2014), the Spar Torus Combination (STC) (Muliawan et al., 2013), and an array of oscillating water columns in a V-shaped concrete large floating platform and one wind turbine combination (O'Sullivan and Murphy, 2013). The combined concept SFC consists of a braceless semisubmersible floating platform, a 5 MW wind turbine, three rotating flap-type WECs, and three catenary mooring lines (see Fig. 1).

Fig. 1 Artistic 3D bird's-eye view of the SFC