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Mooring Solutions for Large Wave Energy Coverters

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The Why and What

Why: Many concepts for wave energy conversion exist today, implemented in a large variety of different devices, many of which are floating structures. Offshore floating structures are exposed to a range of environmental loads, resulting in motions of the device, which need to be restrained in order to ensure station keeping and stability. Usually a mooring system is applied, which by definition is a system of lines connecting the floating device to the seabed. Mooring systems have been widely used by the Oil & Gas and naval sector, giving much experience and knowledge, which have led to a variety of design standards and guidelines. The wave energy sector has to a large extent adapted this experience, but still a large amount of Wave Energy Converters(WECs) have failed due to insufficient mooring [1]. Furthermore, the WEC sector is in a great need of minimizing the overall cost of the mooring in order to make more economical mooring solutions. This need is not as vital in the Oil & Gas sector as mooring only covers a small part of the overall structure cost. This is illustrated by the fact, that cost of mooring only takes up 2% of a floating Oil & Gas structure, stated by [2] and illustrated in Fig. 1. The cost of a mooring for a WEC takes up 18% of the total cost and by some authors, such as [1], is estimated to take up to 30%.

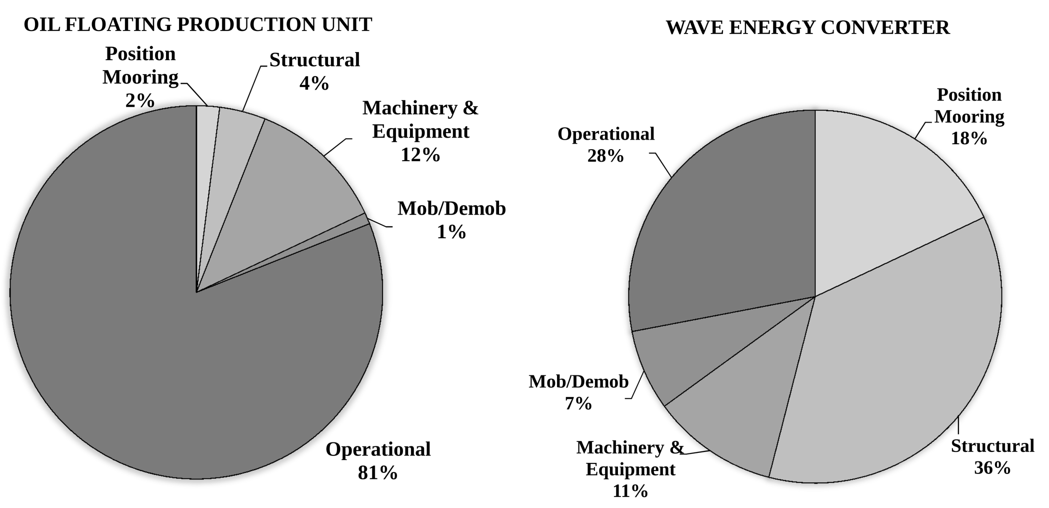

Fig. 1: Cost breakdown of WEC and oil floating production unit.

What: The aim of this study is to investigate and design cost optimized mooring systems and define design procedures and tools. The following main tasks are in focus.

- Define the current state of the mooring design for large floating WECs.
- Preliminary Quasi-static mooring analysis
- Investigation of dynamic mooring analysis tools
- Full dynamic mooring analysis of relevant moooring systems
- Cost evaluation and investigation of potential cost reduction

Involved WECs

The present study investigates the mooring systems of four WECs, defined as being large floating structures where mooring is not an active part of the energy absorption. The four devices are:

- Floating Power Plant
- KNSwing
- LEANCON Wave Energy
- Wave Dragon

Large Floating WECs

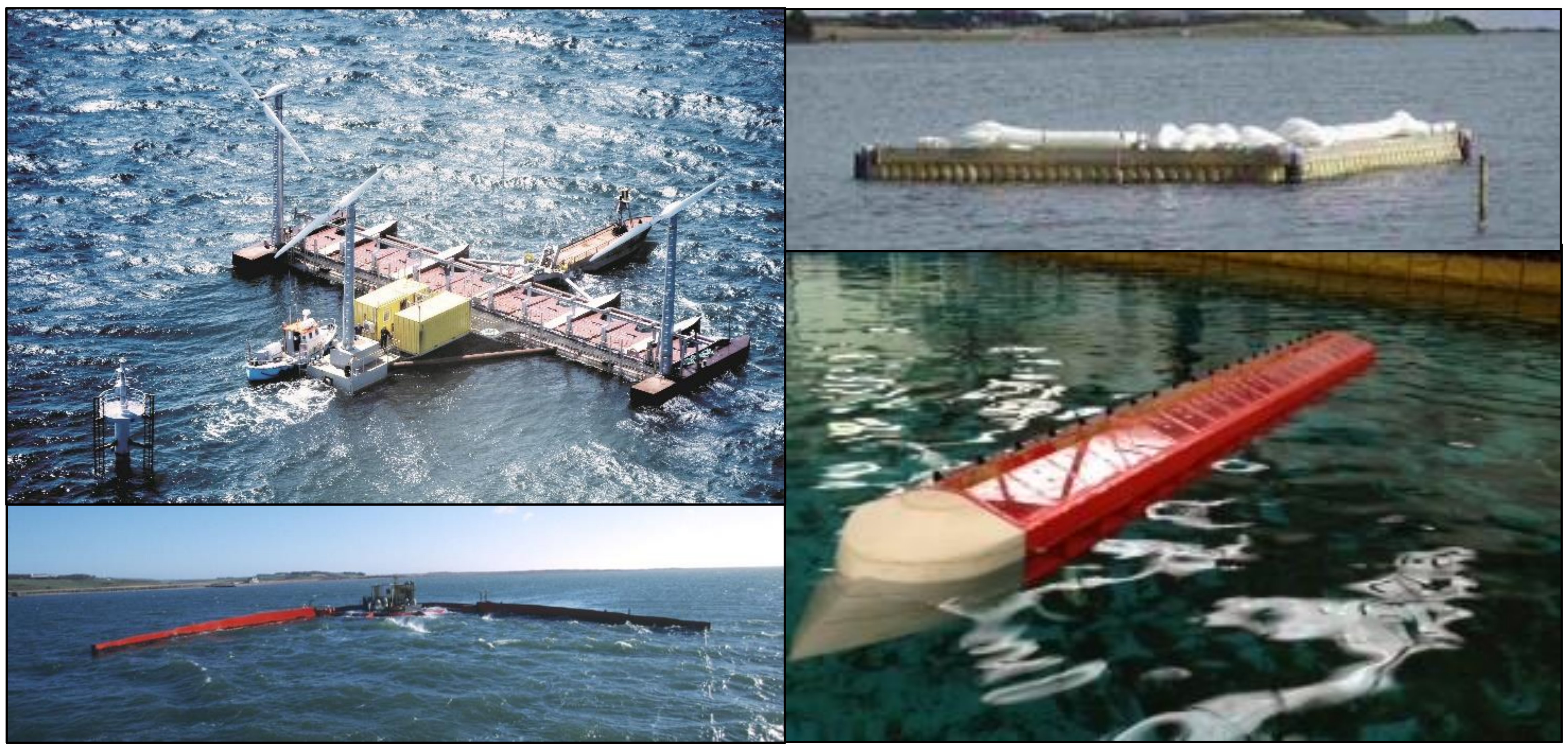

Fig. 2: Examples of large floating WEC, including Floating Power Plant, LEANCON Wave Energy, Wave Dragon and KNSwing.

Current Mooring Design

The involved WEC developers have by now in great extent based the mooring design on the existing experience in the Oil & Gas sector. Still, all systems are in an early state and a final design has not yet been achieved. In the current design a variety of procedures and design criteria has been stated, and only a few are following the design standards for offshore floating structures. Especially the lack of focus on all environmental loads are general for the designed system. The mooring systems by now cover (a) Spread systems, (b) CALM systems, (c) SALM systems and (d) turret systems (cf. Fig. 3).

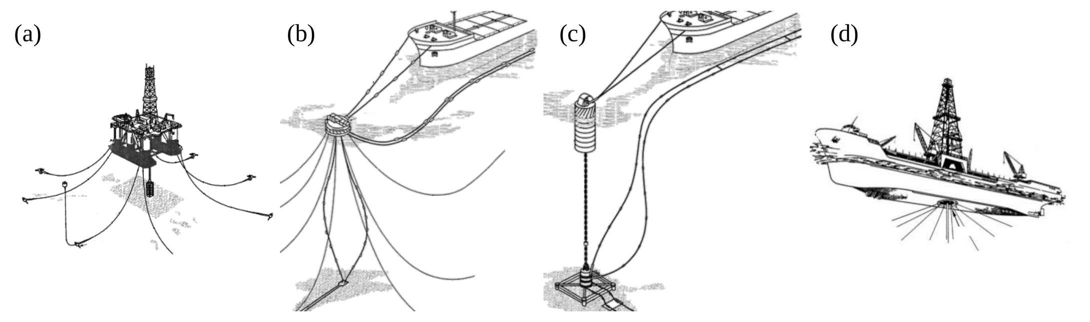

Fig. 3: (a) Spread mooring system, (b) CALM system, (c) SALM system and (d) turret mooring system. Adapted from [3].

These types of mooring systems forms the basis for the present study.

Quasi-Static Analysis

In offshore Oil & Gas and naval sectors, mooring systems are often modelled by a quasi-static approach, justified by the very large structures and corresponding masses. The responses of these structures will be very low in most conditions and the induced velocities of an insignificant size. For most WECs, this is not a valid argument, and much larger motion amplitudes are accepted compared to the Oil & Gas sector, giving lower forces on the WECs. For the large structures considered in this study, the assumptions of low responses might be valid in operational conditions, but for the extreme events, a more advanced dynamic analysis is needed.

A preliminary quasi-static analysis will form the baseline for choosing systems of interest and materials to investigate in details.

Full dynamic analysis

In the final design, a dynamic analysis of the mooring for WEC is necessary, which includes all dynamic effects. In this analysis, the motions of the connection point between floater and cable are imported into a dynamic cable solver, which calculates the dynamic forces in the cables. The dynamic part will be of paramount importance for the assessment of the maximum loads.
A range of different solvers exist, and some examples are listed below.

- ANSYS Aqwa
- Flexcom
- Orcaflex
- ProteusDS
- Sesam DeepC

Many of these software are not aimed at mooring design for WECs and the conditions in which they will be deployed. An investigation of the technical specification of a range of software is undergoing work, and is intended to clarify what software that can be used in a full dynamic mooring analysis. The outcome of this analysis will be an optimized mooring design for each of the devices.

Experimental Work

An amount of experimental work and results will be implemented in the study for validation of numerical models, results etc. These tests covers both small-scale laboratory tests and offshore large-scale testing.

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