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Introduction

The MERiFIC Project

MERiFIC is an EU project linking Cornwall and Finistère through the ERDF INTERREG IVa France (Manche) England programme. The project seeks to advance the adoption of marine energy in Cornwall and Finistère, with particular focus on the island communities of WKH 3DUF QDWXUHO PDULQ G¶,URLVH and the Isles of Scilly. Partners include Cornwall Council, University of Exeter, University of Plymouth and Cornwall Marine Network from the UK, and Conseil général du Finistère, Pôle Mer Bretagne, Technôpole Brest Iroise, IFREMER and Bretagne Développement Innovation from France.

MERiFIC was launched on 13th September at the National Maritime Museum Cornwall and runs until June 2014. During this time, the partners aim to

- Develop and share a common understanding of existing marine energy resource assessment techniques and terminology;
- ,GHQWLI\ VLJQLILFDQW PDULQH HQHUJ\ UHVRXUFH µKRW focussing on the island communities of the Isles of Scilly and Parc Naturel Marin G¶,URLVH
- Define infrastructure issues and requirements for the deployment of marine energy technologies between island and mainland communities;
- Identify, share and implement best practice policies to encourage and support the deployment of marine renewables;
- Identify best practice case studies and opportunities for businesses across the two regions to participate in supply chains for the marine energy sector;
- Share best practices and trial new methods of stakeholder engagement, in order to secure wider understanding and acceptance of the marine renewables agenda;
- Develop and deliver a range of case studies, tool kits and resources that will assist other regions.

To facilitate this, the project is broken down into a series of work packages:

WP1: Project Preparation
WP2: Project Management
WP3: Technology Support
WP4: Policy Issues
WP5: Sustainable Economic Development
WP6: Stakeholder Engagement
WP7: Communication and Dissemination

Disclaimer:

It is the intention of this document to provide introductory guidance for mooring systems for marine renewable energy devices. Readers are actively encouraged to also seek guidance from certification agencies before embarking on the specification of mooring components and the design of mooring systems. The authors of this document cannot be held liable for any damage, loss or injury resulting from use of these guidelines.

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Related documentation:

As a result of the MERiFIC WP3.5 study *Dynamic behaviours of marine energy devices* the following documents have either been produced or are in preparation:

Conference and journal publications	MERiFIC deliverables
Weller SD, Davies P, Thies PR, Harnois V, Johanning L. (2012) Durability of synthetic mooring lines for ocean energy devices, Proceedings of the 4th International Conference on Ocean Energy, Dublin, Ireland	D3.4.2: Cross border laboratory and field test procedures
Thies PR, Johanning L, Gordelier T, Vickers A, Weller S. (2013) Physical component testing to simulate dynamic marine load conditions, Nantes, France, 9th - 14th Jun 2013, Proc. of 32nd ASME Int. Conference on Ocean, Offshore and Arctic Engineering (OMAE), Nantes, France.	D3.5.1: Testing of synthetic fibre ropes
Weller S.D., Davies P. and Johanning L. (2013) The Influence of Load History on Synthetic Rope Response. Proceedings of the 10th European Wave and Tidal Energy Conference, Aalborg, Denmark	D3.5.2: Guidance on the use of synthetic ropes for marine energy devices
Weller S.D., Davies, P., Vickers, A.W. and Johanning, L. Synthetic Rope Responses in the Context of Load History: Operational Performance. *In-review*	D3.5.3: Best practice report - mooring of floating marine renewable energy devices
Weller S.D., Davies, P., Vickers, A.W. and Johanning, L. Synthetic Rope Responses in the Context of Load History: The Influence of Aging. *In preparation*	
Harnois, V., Weller, S., Le Boulluec, M., Davies, P., Le Roux, D., Soule, V. and Johanning, L. Experimental and Numerical Investigation of a Small-scale Mooring Test Facility model. *In preparation*	

1 Terms

ABS: American Bureau of Shipping

ALS: Accident limit state

API:

-TerTer

2 Background

The purpose of an offshore mooring system is primarily to provide sufficient restraint to keep surface or sub-surface equipment on position and minimise the combined effects of wind, current and wave loads on the floating structure. This has particular importance for safety critical equipment (e.g. manned equipment such as oil and gas platforms, floating production, storage and offloading vessels and auxiliary equipment) where the consequences of failure could result in loss of life, environmental disaster or interruption of operations. In terms of size and mass there are some similarities with the mooring systems of MRE devices which have large support structures (e.g. floating wind turbines and proposed multi-purpose platforms, Figure 1). Unwanted and possibly damaging motions can be minimised by designing the moored system (comprising the floating structure and mooring system) to have natural response periods which do not correspond to the excitation frequencies of environmental loading, such as first-order or second-order wave excitation or other excitation forces (Figure 2).

Figure 1: MRE devices with supporting structures (*from left* D U W L V W ¶ V LWinFlo H V V L R Q concept (source: WinFlo), prototype of the *Poseidon Floating Power Plant* (source: Knud E Hansen A/S) D Q G D U W L V W ¶ V LW2Power concept (source: Pelagic Power)

In general MRE devices which are small compared to the incident wave length (i.e. wave energy converters or WECs) will dynamically respond to first-order and second-order wave loading as well as the combined effects of wind and currents. There is usually strong coupling between the device and mooring system responses [1,2] and hence complex motions can occur [3] which may be large if the system response is resonant. One particular class of devices; WECs are designed to either i) generate electricity or ii) be used to desalinate water. These devices are typically designed for optimal performance at first-order excitation periods (Figure 2) and therefore responses close to resonant are possible in one or more modes of motion. Clearly the possibility of resonant motions occurring will have implications for the load cases used in the design of MRE mooring system and the specification of mooring components.

Figure 8: Simplified in-service simulation testing approach involving the generation of standardised load-time histories (taken from [30])

Several commercial programs exist which can be used to conduct static, quasi-static and dynamic analysis of complete mooring systems, including (but not limited to) *Orcaflex* by Orcina[17], *Optimoor* by TTI[18] and *Deeplines* by Principia[19]. Although sophisticated, it is not possible to model all of the distinct features of MRE devices using existing mooring system software, such as power take-off systems. *WaveDyn* by GL-Garrad Hassan[20] is one of the first commercially available simulation tools which has been specifically designed for the dynamic response of WECs. Assuming that the device design has been formalised, the procedure for numerical modelling can be split into several stages (Figure 9). It will be noted that the focus of this chart is on numerical modelling of the moored system with contributions from resource assessment modelling and physical testing. However, this approach is not rigid and an indicative study could be conducted with no prior knowledge of the site characteristics, starting from Step 1 (Figure 9).

[17] http://www.orcina.com/SoftwareProducts/OrcaFlex/ (accessed online: 05/10/2013).

[18] http://www.tensiontech.com/software/optimoor.html (accessed online: 05/10/2013).

[19] http://www.principia.fr/expertise-fields-software-products-deeplines-126.html (accessed online: 05/10/2013).

[20] http://www.gl-garradhassan.com/en/software/25900.php (accessed online: 05/10/2013).

5 Summary

Significant cost reductions are required for marine renewable energy to become a competitive electricity generation method that is attractive to investors and utility companies. Aside from the deployment of arrays comprising multiple devices, one key area that has been identified as having potential for cost reductions is the mooring system. A clear challenge therefore exists to design MRE mooring systems which can satisfy their primary role of station-keeping whilst being affordable, durable and readily deployable.

The current approach for mooring system design is to use existing offshore standards geared towards large equipment operating in deep water environments. The motion of this equipment is characteristically small relative to its size. This clearly contrasts the highly dynamic motions that smaller more responsive MRE equipment will experience, particularly for devices designed to operate at or close to resonance in one or more modes of motion. The mooring systems of these devices will experience highly dynamic tensions and potentially be subjected to

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