Development of dynamic submarine MV power cable design solutions for floating offshore renewable energy applications

Marco **MARTA**, Sven **MUELLER-SCHUETZE**, Heiner **OTTERSBERG;** Norddeutsche Seekabelwerke GmbH/General Cable, Nordenham, Germany, marco.marta@nsw.com, Sven.Mueller-Schuetze@nsw.com, Heiner.Ottersberg@nsw.com

Daniel **ISUS FEU**; General Cable, Manlleu, Spain, disus@generalcable.es

Lars **JOHANNING**, Philipp R **THIES**; University of Exeter, Penryn, UK, L.Johanning@exeter.ac.uk, P.R.Thies@exeter.ac.uk

ABSTRACT

This paper reviews approaches to design, modelling and testing of submarine dynamic power cables given the systems requirements for floating offshore renewable energy (ORE). It mainly focuses on the global loading regime and internal mechanical stress estimation in highly dynamic working conditions as well as the assessment of cable mechanical properties, strength and fatigue life.

KEYWORDS

Power cable, highly dynamic, subsea, offshore, renewable energy, fatigue life, global loads, stress distribution

INTRODUCTION

Floating offshore renewable energy (ORE) can potentially provide a significant share of the future energy generation mix. Floating foundations greatly expand offshore wind turbine deployment areas by overcoming water depth constraints. Additionally, they open up opportunities for changes to manufacturing and deployment practices that may deliver significant cost reductions. Few full size floating wind turbine prototypes have been installed with more deployments announced [1]. Developers of both wave and tidal energy converters are also deploying an increasing number of floating prototypes [2].

Most floating ORE connections to the power grid require dynamic inter-array submarine power cables. These cables must continuously withstand dynamic mechanical loading regimes during their lifetime.

Devices are typically deployed in high environmental energy density locations and must withstand full year-round environmental conditions for the project lifetime of typically over 20 years. Most technologies are designed to work in relatively shallow water (i.e. up to few hundred metres), some to respond to wave motion in highly dynamic fashion. Consequently, dynamic power cables between floating hosts and the seabed lie mostly in the wave zone and are subjected to very severe loading regimes. These power cables must be designed to operate in highly dynamic conditions with cyclical axial loading sequences and continuous bending cycles due to both environmental loads and the relative motion of the device system components.

Failures risks include tensile failures, buckling due to extreme axial loads sequences, as well as bending failure due to extreme bending loads and related cable deformation below the specified minimum bending radius. Torque balance and cross-section stress balance are fundamental requirements for any dynamic cable. However, dynamic cables for floating ORE applications are expected to require special care and full assessment of their dynamic behaviour in operation as they are subjected to a loading regime where the potential for hockling and kinking is significantly amplified.

Inherent compliance together with typical internal components arrangement and geometry make dynamic cables especially vulnerable to alternating bending loads where radially compressed layers/elements are subjected to relative motion resulting in significant risk of wear, deformation and the degradation of physical properties.

Continuous dynamic cyclic loading during operation also exposes these cables to high risk of fatigue failure. Thies et al [3] assess the global loading regime and fatigue failure modes for a submarine cable connected to wave energy converter. Nasution et al [4, 5] investigate fatigue life of stranded copper conductors subjected to severe combined tensile and bending loads.

A research project was carried out with the objective of identifying suitable design solutions for power cables in highly dynamic operating conditions in order to ensuring safe, reliable and cost effective electrical connections for floating ORE. This involved reviewing and strengthening the hydrodynamic and mechanical modelling methodology applied in dynamic cable design. A highly dynamic test cable was then designed and manufactured applying both best practices and novel solutions. Finally, the cable performance was thoroughly assessed through comprehensive mechanical testing and analysis.

METHODOLOGY

Present submarine cables design and manufacturing practices rely on a combination of theoretical and empirical models selected and developed through years of experience. A number of specialist finite element analysis (FEA) software applications are used for loads/stress analysis and design optimization.

However, uncertainties still remain regarding the precise characterisation of stresses and strains acting within a cable structure and their effects. From a structural mechanics prospective, submarine cable can be seen as an assembly of both metallic and polymeric elements with significantly different geometries and material properties. The widely dissimilar deformation responses to loading for the different elements, the effects of the interaction between adjacent components as produced by friction and stick-slip regimes on stress distribution and the impact on the individual elements material surface finish and overall mechanical properties of minimal changes in the manufacturing process are only a few of the substantial challenges to accurately model loads and related effects through numerical analysis.