Weight in water considerations for offshore wind farm subsea array cables with aluminium conductors

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ABSTRACT

The reduced weight of aluminium conductors compared to copper can be a disadvantage in the subsea environment. This is particularly relevant to offshore wind array cables which do not normally include lead sheaths which provide additional self-weight.

Requirements around cable weight (dry and submerged), and how these values should be calculated and tested, are not currently addressed in the relevant standards.

This paper examines these issues, starting with the installation and installed conditions that may cause concerns, then how submerged weight is defined, calculated and measured. Examples are given for array cables at both 66kV and 132kV. The intention is to help move to a convergence of calculation methodologies and test verification procedures.

KEYWORDS

Added Mass: Aluminium; Array Cable; Specific Gravity; Terminal Velocity; Weight in Water; Weight in Water to Diameter Ratio; Array Cables

INTRODUCTION

The reduced weight of aluminium conductors (metal density 2710 kg/m^3) compared to copper conductors (metal density 8940 kg/m^3) is generally an advantage for land and underground applications, however can be a disadvantage in the subsea environment. Inadequate weight in water (also called submerged weight) can lead to implications for achieving on-bottom stability; for reducing the allowable envelope of installation environmental conditions; and for ensuring stable burial of the cable into the seabed.

This can be particularly critical for array cables between turbines in offshore wind farms, which do not have the heavy lead sheath ballasting available to higher voltage export cables.

This paper sets out to outline why this is important, how weight in water is calculated, then examples at both 66 kV and for potential higher voltage future array cables are considered, before proposing a standardised methodology for test measurement of weight in water.

WHY DOES WEIGHT IN WATER MATTER?

One concern that has been observed is in the **jet burial** of lightweight cables. The action of jetting away the seabed throws sand and silt particles into suspension. Because these particles are denser than sea water, they slowly sink, but in the meantime form a fluid with a Specific Gravity (SG) greater than 1.0, where Specific Gravity is defined as density divided by the density of the reference substance, which in this case is seawater. If the Specific Gravity of this fluid exceeds the Specific Gravity of the cable, the cable will tend to float up, and the burial attempt may be ineffective. In practice there are multiple other variables at play including cable stiffness, cable tension, speed of burial and other environmental conditions which impact jet burial.

A second key concern is for **on-bottom stability**. Detail calculation takes into account not just cable and seabed parameters, but also water depth, wave and current characteristics. This can become very complex, see DNV Recommended Practice F109 [2] as implemented into software such as 'Stablelines'.

The two main determinants of on-bottom stability are the drag force trying to displace the cable (which is a function of cable diameter and water flow velocity), and the stabilising friction between the cable and the seabed, which is proportional to the cable weight in water.

Hence a simplified approach to on-bottom stability is to consider the critical water flow velocity (u) over the cable lying on the seabed for the onset of movement, accounting for only the weight of cable in water (W_s x g), cable diameter (D), seawater density (ρ_S) , cable/seabed friction coefficient (μ), and coefficients for drag (C_D) and lift (C_L), which gives:

$$u^2 = 2W_S g \,/\, [\, D\, \rho_S\, (C_D /\mu + C_L)\,] \qquad [1]$$

This shows the importance of the ratio of Weight in seawater to Diameter (W_S/D) in determining on-bottom stability.

For the more complex and complete analysis, Vintermyr [4] analysed a wide range of cables, umbilicals and pipelines with W_S/D ratios of between 17 – 600 kg/m^2 using Stable-lines for different global weather conditions and likewise concluded that 'the submerged weight to outer diameter ratio is the governing parameter of a cable's on-bottom stability'.

However, because weather, water depth and seabed conditions vary greatly, there is no single 'rule of thumb' minimum required W_S/D ratio for stability, as it is highly dependent on the location.

For example, it has been seen in project analysis that there are cases where a cable minimum SG of 1.8 is insufficient to ensure a high enough W_S/D ratio to ensure stability in the duration between cable laying and burial operations, or between cable laying and subsequent rock berm placement, and hence higher minimum cable SG requirements of 2.2 were required.

A third consideration is around **dynamic behaviour during installation**. One example is how quickly a cable falls into the trench when being buried, which may limit maximum burial speed to give effective burial. Another example is in defining at what sea state the installation weather window for a particular cable lay vessel may be limited, for example by the limit of allowable compression in the cable, or where the minimum allowed cable bend radius is breached, which can be negatively affected by lighter cables. A further example is when laying cables around tight bends on the seabed, where lighter cables are less stable during installation. In these cases a key underlying element is the terminal velocity (v) of the cable under free fall conditions,