DEVELOPMENT AND QUALIFICATION OF DEEPEST WATER POWER UMBILICAL

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ABSTRACT

This paper describes the world's first umbilical system to deliver substantial power at 2700m water depth. The system is developed to deliver power to subsea pumps through a dynamic power cable hanging from a moored turret buoy in a catenary installation down to the seabed.

Attention is focused on the development, design and qualification of the umbilical and its main components, the power cables, performed in close cooperation between the different companies involved.

KEYWORDS

Power umbilical, dynamic, submarine, deep water, boosting, pumps

INTRODUCTION

As the oil and gas industry looks for ways to keep pace with the growing worldwide demand for oil, subsea developments are moving into ever increasing water depths and operators are looking towards subsea boosting technology as a means of getting the most out of their reservoirs. The power distribution umbilicals, which are needed to supply electrical power to the subsea boosting pumps, will be challenged by more extreme tension loads due to the deeper waters.

This paper presents a technical description of a power umbilical to be installed in the area of the central Gulf of Mexico at 2700m water depth; the first of its kind to transmit power over this depth sufficient to power subsea boosting pumps. The requirements of the power umbilical system required a transmission of 1.7MVA including two three-phase supplies and a spare three-phase circuit; therefore, a total of nine cables, rated 12/20 kV with a conductor cross-sectional area of 150mm^2 each. In addition, due to the long length of the umbilical cable, including dynamic (that part of the umbilical suspended in water) and static (that part of the umbilical laying on the seabed) sections, 2 sets of splices were included in static section.

Attention is focused on the development and design principles of the umbilical and its main components, presenting the challenges encountered, which to date are unique. Also, a thorough qualification program is described that has verified the umbilical's ability to survive the rigours of installation and operational life at the most extreme conditions.

ULTRA DEEPWATER CHALLENGES

The traditional way to limit the strain in umbilicals is to increase the axial stiffness by adding steel armouring. But for very deep water applications, steel as armouring material does not work efficiently to reduce the strain of an umbilical. If a structural member suspended from a top point is hanging vertically and exposed to its gravity load only, the strain close to the hang-off point is proportional to the free hanging length and density, but the opposite applies in relation to its stiffness. Therefore materials used for stiffness enhancement lose effectiveness as the water depth grows. At a certain water depth the added weight from steel armouring increases the strain rather than reducing it.

This has made the industry look for light but still stiff material for umbilical stiffness enhancement. As a result of many years of development and testing, a carbon fibre rod reinforced umbilical system has been developed and patented. The carbon fibre rods, which are bundled into the umbilical alongside the other elements in the umbilical, have about the same stiffness but only one fifth of the density compared to steel. This change has eliminated all practical water depth limitations in terms of strain and stress induced by the gravity loads, and has been used in a number of steel tube umbilicals over the last several years.

The control of strain is particularly important for high and medium voltage electrical power umbilicals. A typical safe long-term strain limitation of power cables is in the range of 0.15%; this can easily be achieved for dynamic power umbilicals using the carbon fibre rod system. Furthermore, by use of a special hang-off system described below (Umbilical mechanical properties), the cables are "free floating" in the dynamic bending zone, thus avoiding any uncontrolled loads upon the cables in the zone and limiting the strain to that caused by bending only.

Comparison of carbon fibre rods vs. steel as armouring material

In shallow waters in combination with a harsh environment a high weight to diameter ratio is required for the dynamic umbilicals in order to perform well. This is not the case for power umbilicals in deep waters. Instead, the primary concern is to reduce the global strain of the umbilical system. The control of global strain of an umbilical in deep waters may be achieved by two methods: reduction of the underwater weight, and/or by increasing the axial stiffness of the umbilical.

The following example provides a comparison of steel versus carbon fibre rods as a stiffness enhancement system for an umbilical:

The density of steel is 7850kg/m^3 in air compared to 1600kg/m3 for carbon fibre reinforced vinylester rods. The stiffness modulus of steel is 200000 MPa compared to 150000 MPa of a composite carbon fibre reinforced rod. As the strain is proportional to the weight and the inverse applies to the stiffness, reducing strain by the use of