NEW SUBSEA OPTICAL FIBRE JUNCTION BOX FOR REDUCED TENSILE LOAD APPLICATIONS

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Abstract: Composite cables have at least one fibre optic cable used for monitoring, control and maintenance of the system. These fibre optic cables are normally of a simple construction; fibres contained within a hermetically sealed pressure 'fibre tube' with an extruded insulating layer. In many applications field and repair joints the re-instated optical fibre joint housing is contained within a larger housing where the optical cable is not required to support the cable weight during deployment nor does it require additional protection. This paper describes one such tailored solution utilising expertise gathered from the very first subsea fibre optic telecoms systems.

1. INTRODUCTION

The use of fibre optics for offshore applications[1] has been utilised for some time to improve communications and system monitoring between platforms and hubs within the oil & gas, energy renewables (windfarms, wave, tidal) and seabed monitoring systems. This can present some different conditions for jointing of the fibre optic cable when compared to telecommunications cable applications.

This allows a different design approach for a joint specifically developed for zero and/or low tension applications, it will also lead to a reduced testing and qualification programme. There can also be savings made for supplied operational kits, equipment, jointer training and assembly times, providing further benefits to users.

2. TELECOMS AND POWER CABLES SERVICE CONDITIONS

For the installation and maintenance of subsea telecoms fibre optic systems the assembled cable joints are deployed 'in-line' with the cable. This requires that the joint is capable of withstanding the same installation and recovery loads that are applied to the cable.[2]

During deployment the telecoms cable and joint will normally experience the tension due to cable weight and will be surface laid or buried with zero permanent tension.

Figure 1 Telecoms Optical Fibre Joint deployment in-line with cable

The greatest loads occur however during recovery operations where the dynamic tensions are typically twice the cables weight in water which for a repeatered LW joint can be between 50kN to 80kN from

[1] **Rutzen, Winfried** 'Fiber-optic connectivity for offshore oil & gas applications: more bandwidth, more possibilities, more benefit' Suboptic 2013

[2] ***International cable Protection committee (ICPC)***'Submarine cables and the oceans: connecting the world'. ISBN978-0-9563387-2-3

8km water depth.[3],[4] This will be less for unrepeatered systems which usually have a shallower maximum water depth. This dynamic recovery load will be less than the maximum operational load (safe working load) of the cable which is specified as the Nominal Transient Tensile Strength (NTTS)[5]. This is the maximum tension that can be applied to the cable during a cumulative period of one hour. The peak dynamic load occurs as the cable and joint passes over the recovery sheave of the repair vessel.

The joint, when recovered in-line with the cable, for reasons of safety must not significantly weaken the ultimate tensile strength (UTS) of the cable [also known as cable Breaking Load (CBL)]. For cable handling procedures this is typically specified as 90% of the cable's UTS/CBL.[5] A deep water lightweight (LW) cable has a typical UTS of 100kN and a heavy double armour (DA) cable >700kN.

For subsea XLPE AC power cables rigid repair joints are such that the outer armour wires are restrained and linked together so that between the armour terminations the elements of the composite cable are not tensioned. As the power core connectors are enclosed within a housing between the armour terminations and this provides space for the fibre optic cable joint(s). Rigid power cable joints are not normally deployed in line with the cable but under special handling configurations [6].

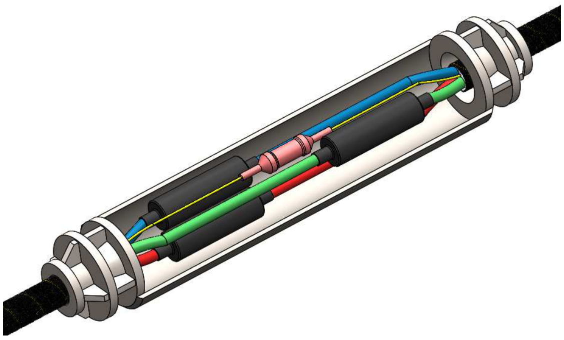

Figure 2 Cutaway of Rigid Power Cable Repair Joint

As the fibre optic cable is not deployed under its own weight there will not be deployment and recovery tensions, twist and torsion applied to the joint. The tension and torque that is applied to the fibre optic cable within the power cable joint will be limited to that induced by handling and the turns applied to stow the excess fibre optic cable (if any) before joint closure.

The power cable joint also differs from the telecoms fibre optic joint in steady state service temperature. A fibre optic joint is exposed to the same environmental and ambient conditions of the seabed thorough out its service life but for a power cable the steady state temperature is elevated significantly above the seabed ambient temperature due to the inherent current leakage (Ohmic loses) of power transmission and will cycle with variations in the sea bed temperature. The mechanical and material performance implications from this thermal stress need to be considered.

Subsea power cables have, compared to telecoms cables, a shallower operating depth, typically no more than 100metres

[3] **Sakaguchi, Mareto et al** 'Development of Advanced Small Diameter Submarine cable' Suboptic 2013

[4] **Boulanger, Patricia et al** 'OALC-5, an Optimised Solution for Regional Systems' Suboptic 2007

[5] **Recommendation ITU-T G.976** 'Test methods applicable to optical fibre submarine cable systems'

[6] **Worzyk, Thomas** 'Submarine Power Cable design, Installation, repair Environmental Aspects' ISBN 978-3-642-01269-3

although deeper water (<2,000 metres) systems are a consideration. A trans-oceanic 'repeatered' LW cable joint can be deployed to 8,000 metres with a resultant hyperbaric pressure in excess of 83MPa.

3. FIBRE OPTIC CABLES IN COMPOSITE POWER CABLES

Within the UK offshore windfarm market, as elsewhere, the fibre optic cable is often integrated with the power core(s) as a composite cable for the export and array XLPE AC power cables.

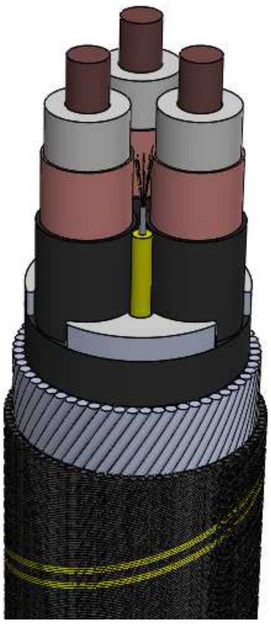

Figure 2 Power Cable showing Optical Fibre Cable

In its most basic construction the fibre optic cable within the power cable has a simplified construction compared to its telecoms counterpart: the optical fibres are contained within a hermetically sealed metallic 'loose' tube[7], normally stainless steel, surrounded by an outer extruded polythene sheath (cable **A** in Figure 3). This is the modal type of construction however a study of the fibre optic cables within export cables for the Offshore Windfarms supplying the UK and the platform array cables shows some variations which are of consideration when designing a suitable fibre optic cable repair joint.

The first variation is to change the hermetic tube from a stainless steel tube to one of copper or to add a copper tape layer over the stainless steel layer (Cable **B** Figure 3) to improve the electrical resistance path if required. When sealed a copper layer is a superior hydrogen barrier to stainless steel.
Some cables have a layer of helically wound wires applied on top of the fibre tube or polyethylene (Cables **C** and **D** Figure 3). This provides additional tensile strength and crush resistance to the cable. These are typically high tensile or stainless steel although aluminium has been stated.

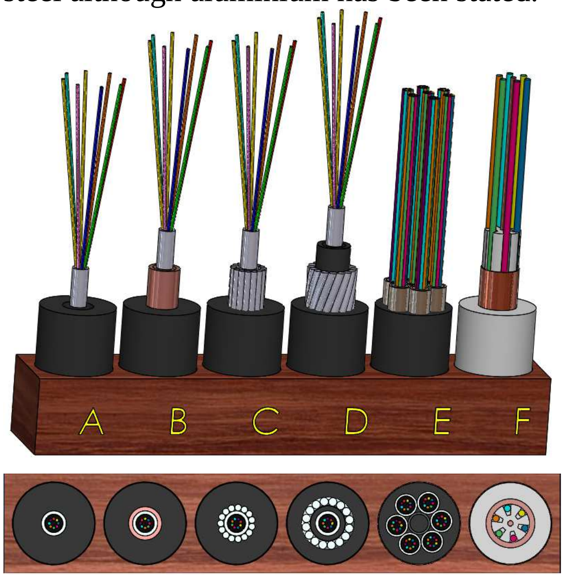

Figure 3 Optical Power Joint

In some instances the single fibre tube has been replaced with a bundle of fibre tubes and or fillers (Cable **E** Figure 3) or indeed a helically wound fibre tube within the armour layer. There is also use of 'V' grooved slotted core instead of the fibre tube (Cable **F** Figure 3).

[7] **Gaillard, Pierre et al** 'New Unrepeatered Cable Design Testing Methodology and Results' 47th IWCS Conference 1998

Occasionally two separate fibre optic cables are incorporated within the power core interstices, requiring two fibre optic joints.

The number of fibres contained within each cable also varies but is typically 24 or 48 fibres with some instances of 96 fibres. The cable diameter for a polyethylene (PE) sheathed cable is between ø10 and ø15mm and a tensile strength less than 15kN

4. NEW SUBSEA OPTICAL FIBRE JUNCTION BOX

Having studied the engineering requirements for a power cable fibre optic joint box a design has been developed specifically for the application building on the jointing experience and knowledge Global Marine has acquired from the very beginning of the subsea fibre optic cable technology [8].

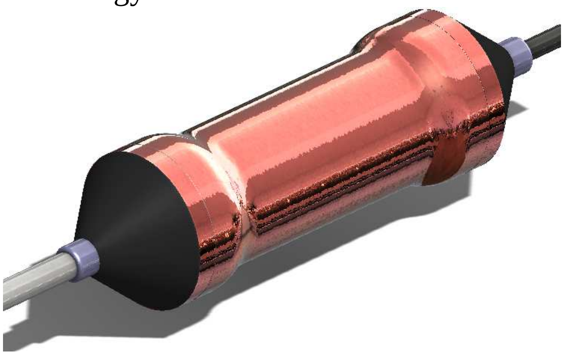

Figure 4 Optical Power Joint

A cylindrical joint, overall length 30cm, outside diameter 9cm, has been designed to minimise assembly time, less than 6 hours for a 24 fibre cable, using minimal tooling and assembly techniques to cover the largest range of power cable fibre optic cable variations between ø8 and ø16mm. The maximum fibre count is currently 96 fibres using fusion spliced, micro splint splice encapsulations with an option for 192 fibres being evaluated.

[8] **Ash, Stewart** 'From Elekron to 'e' Commerce' section 4"The Light Fantastic" ISBN0-9539078-0-5

The pressure housing has been designed to withstand water pressure in excess of 2km water depth (6km water depth has been demonstrated) and a maximum tension greater than 20kN (tested to failure in excess of 100kN).

The joint has been designed for hydrogen management using metallic seals to continue the protection of the cable's hydrogen barrier and inhibit the attenuation of the optical fibre signal.[9]

The metallic pressure housing is insulated using either heatshrink or polyurethane moulding. This provides additional water immersion integrity but also allows for insulation of the electrical connector and toning of the cable for fault location.

5. JOINT TESTING

For telecoms applications the ITU-T: G 976 (07/2010) standard 'Test methods applicable to optical fibre submarine cable systems' details a fairly comprehensive list of recommended tests to demonstrate the reliability of joints and cable within optical fibre submarine cable systems. By its own omission "it should also be recognized that some test methods are specific to optical fibre submarine cable systems and of little or no use elsewhere"[5] so care needs to be taken when applying these recommendations to power cable applications. The nearest power cable equivalents of the ITU-T:G976 standards: CIGRE TB 623[10] and CIGRE TB 490[11] offer little guidance for the specific requirements of the fibre optic cable and joint other than to recommend that the

[9] **Jarvis, Adrian et al** 'Testing of High reliability Seals for Submerged Equipment' Suboptic 2013
[10] **CIGRE TB 623** 'Recommendations for Mechanical Testing of Submarine Cables'
[11] **CIGRE TB 490** 'Recommendations for Testing of Long AC Submarine Cables with Extruded Insulation for System Voltage above 30 (36) to 500 (550) kV

fibre optic cable (and joint) is tested along with the power joint.

Although drafted for terrestrial applications and not directly related to subsea applications the Telcordia GR-771 requirements for 'Generic Requirements for Fiber Optic Splice Closures'[12] can be studied for Environmentally Sealed Closures (ESC) which might be installed in manholes, likely to flood.

Considering these recommendations and requirements and Global Marine's experience in fibre optic jointing applications a test programme is to be devised for the joint to verify its mechanical, electrical, optical, thermal, environmental and handling performance. The tests would first be completed as maximum design load 'type' tests for the joint and then a smaller subset repeated for the specific cable types:

Tensile test
Fatigue test
Pressure test
Temperature cycling fatigue
Steady state temperature
Bump and vibration
Hydrogen management testing
Electrical resistance
Insulation resistance

Finally the joint, integrated within a power cable joint, will be subjected to a sea trial. This procedure also verifies the operational suitability of the manufactured piece parts, equipment, construction documentation, jointer training and ships handling instructions.

6. OTHER APPLICATIONS

Outside of export and array power cable rigid repair joints the application of a low tension joint can be made to telecoms cables bundled to other cables such as HVDC cables (single power core) where the weight of the telecoms cable is supported by the larger power cable. For these applications fibre optic cable has additional protection by the application of outer armouring wires in either single armour or double armour configurations. For these applications the joint will have external armour terminations and joint sleeve protection much like a typical telecoms fibre optic joint.

Another area for low tension cable joints is in direct electrical heating (DEH) systems where oil and gas pipelines are heated to prevent the formation of hydrates. The optical fibre in a cable coupled to the pipeline is monitored using distributed temperature sensor (DTS) imaging to temperature profile the system.

7. CONCLUSION

The joint developed has already been subjected to a wide range of engineering trials and design iterations demonstrating its suitability for the application.

Over the forthcoming year (2016) the joint shall undergo formal qualification testing at Global Marine Systems Limited's UK test facility so that it will available from Q2 2017.

Figure 5 Cable Test Facilities (Pressure)

[12] **Telcordia GR-771** requirements for 'Generic Requirements for Fiber Optic Splice Closures'