SUSTAINABILITY OF SUBSEA OPTIC FIBRE CABLES IN THE NORTH SEA

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Abstract: Increasing the lifetime of a subsea fibre optic cable system lowers system lifecycle cost. Furthermore, it reduces the carbon footprint through minimizing marine operations for repair and cable replacements. In this paper we discuss the lifetime of subsea fibre optic cables and subsea communication systems. As a case-study we look into one of Tampnet's oldest cables and discuss how life expectancy of deployed subsea cables are extended via a strategy based on deploying passive, unrepeated fibre optical cables in the network combined with strategic upgrades on the dry side, utilizing the latest technological developments within amplification and transmission technology.

Tampnet installed its first cables in 1998 in the North Sea region. In several stages including very recently, it was decided to add branching units to the existing cable system for further expansion, enabling re-routing of some of the fibres into a meshed network design, whilst reusing the existing older fibre infrastructure. Before this decision was taken, degradation of the cable due to aging was evaluated. The cables had been buried into the seabed for protection, typically 0.5 to 1.0 meter under the seabed. Attenuation of the fibres was measured from the platform where the cable was terminated The measurements showed that the attenuation of the fibres was consistently lower than the specification of the cable at the time it was installed and visual inspection showed very little corrosion.

1. INTRODUCTION

Increasing the lifetime of a subsea fibre optic cable system lowers system lifecycle cost. Furthermore, it reduces the carbon footprint through minimizing marine operations for repair and cable replacements. In this paper we discuss the lifetime of subsea fibre optic cables and subsea communication systems. As a case-study we look into one of Tampnet's oldest cables and discuss how life expectancy of deployed subsea cables are extended via a strategy based on deploying passive, unrepeated fibre optical cables in the network combined with strategic upgrades on the dry side, utilizing the latest technological developments within amplification and transmission technology.

Tampnet installed its first cable in 1998 in the North Sea region. The cable type was the Nexans URC-1 cable [1]. Later it was decided to add branching units to the existing cable for further expansion, enabling re-routing of some of the fibres into a more meshed network design, whilst reusing the existing older fiber infrastructure. Before this decision was taken, degradation of the cable due to aging was evaluated. The cables had been buried into the seabed for protection, typically 0.5 to 1.0 meter under the seabed. Attenuation of the fibres was measured from the platform where the cable was terminated (closest to the branching unit). The distance from the branching unit to the platform was approximately 105 km. The measurements showed that the attenuation of the fibres was consistently lower than the specification of the cable at the time it was installed, i.e. $\leq$ 0,19 dB/km@1550 nm. Furthermore, visual inspection of the recovered 20+ year old cable showed very little corrosion, and the cable appears like it did when it was originally delivered.

Building sub-sea networks using un-repeatered, i.e. passive cables has a number of benefits. The cable itself is lighter and simpler due to the power feed that is not needed. Furthermore, a passive cable will have a lower frequency of faults because it is not vulnerable to e.g. shunt-faults caused by the faults in the isolation of the cable causing contact between the power-conductor and seawater. Active sub-sea amplifiers (repeaters) are also components that can contribute to a higher fault frequency, not present when using passive cables.
On the other hand, passive cables limits distance between active repeater stations or cable termination points. By using Remote Optically Pumped (ROPA) and Raman [2] amplification techniques it is however demonstrated that distances of approximately 500 km can be achieved [3]. The ROPA allows remote optical pumping of sub-sea EDFA amplifier elements, avoiding electric-power feeding through a cable. Raman-amplification is implemented through pumping with a high-power laser (typically located in a dry-room) directly into the transmission fibre, extending the reach of the cable span. By combining these techniques, the Tampnet network is implemented using passive fibre cables only, spanning the North-Sea, connecting Oil and Gas installations to Norway and U.K. landing locations. Figure 1. shows the Tampnet network with a span using ROPA amplifier indicated. Additionally, Raman-amplification is applied in several nodes for increasing the signal-to-noise ratio and span-length.

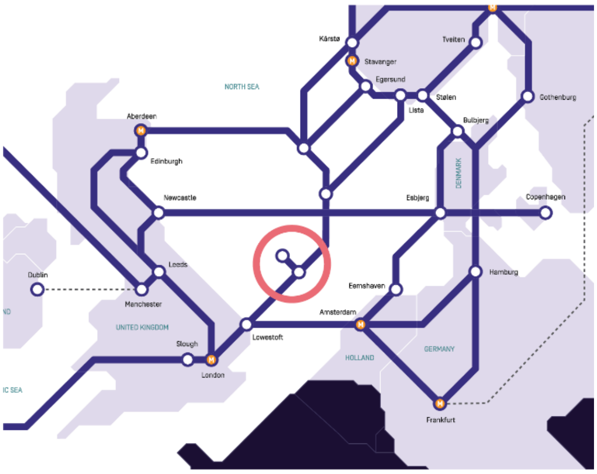

Figure 1: Tampnet fibre-cable network in the North-Sea. The red circle illustrate the use of a ROPA on the cable from the Valhall oil and gas installation, to Lowestoft in the U.K.

In addition to delivering data-transport connections to oil and gas installations, the connections between Norway and U.K. is used for high-capacity international carrier services. Because the path length is minimized due to the use of ROPA, a low-latency path connecting the Nordics to U.K is available using this network.

Furthermore, unlike networks using active repeaters, the passive cable is found to more easily allow additional sub-sea units like e.g. branching units, to be installed after the cable has been deployed. This is because no considerations with respect to power-feeding and handling of the power-conductor is needed when making modifications to the cable.
Adding additional amplifiers in an active cable after deployment due to needs caused by e.g. an added branch and extended span-length, may be complicated in active systems due to added power requirements. For passive cables on the other hand, adding ROPAs may help this problem, pumping the amplifier element in the ROPA through a separate fibre or a separate wavelength in the data-transmission fibre.

Tampnet Submarine Optic Fibre cable system have been selected from Nexans Norway and other major cable suppliers. The NorSeaCom 1 cable system was supplied by Nexans Norway.
The Un-repeatered Fibre Optical Fibre Submarine Cable System between the landing sites in Norway and UK; connected via 5 oil/gas-platforms had a length of about 900 km. (Figure 2).

Figure 2: NorSeaCom 1 Submarine Fibre Optical System.

An overview of the NorSeaCom cable system is shown above, The cables and components are described below. The Qualification of URC-1 cables was carried out in accordance with applicable standard IEC-60794 [4]. Type tests for the URC-1 cable family are described in TR-21-95 [5]. The focus of the design was to develop a secure, highly reliable, and efficient deployment system. Efficient means of operating the optical fibre systems was also important.

2. SUBMARINE OPTIC FIBRE CABLE DESIGN

The URC-1 cable core consists of the single mode fibres (as per ITU-T G.652) inserted into a stainless-steel tube filled with water-blocking and hydrogen-scavenging material. In the North Sea Net project, the subsea to platform cable was fitted with 24/48 fibres, while the main subsea cable lengths were fitted with 24 fibres. The fibre steel tube is protected by a polyethylene inner sheath, layers of armouring wires and outer PP-yarn protection.
The Heavy Single Armoured Cable (SAH), contain one layer of 5 mm galvanised steel wires, the SAH was used for all cable sections except for subsea to platform cable and for pipeline or cable crossings sections.

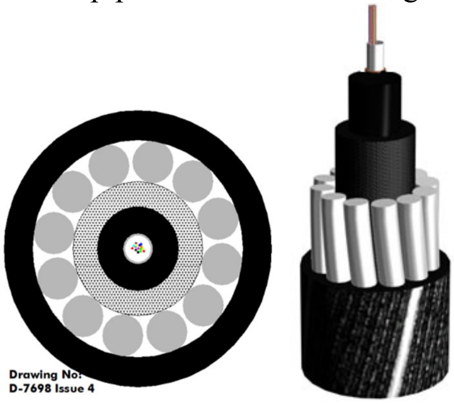

Figure 3: URC-1 SAH (G24 QERA R5)

The Heavy Armoured Cable (HA) was used for pipeline/cable crossings, static subsea to platform cable and for areas with high risk of limited burial (sand dunes) and risk of trawlers/fishing gear damage. The cable core is protected with double layers of armouring wires (4.2/5.0 mm).

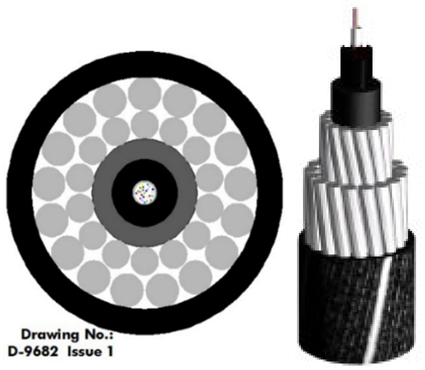

Figure 4: URC-1 HA(G24/G48 QEVA R4.2/5)

As dynamic riser cable subsea to platform the Rock Armoured Cable (RA) with three layers of armouring wires (5mm) were used. The riser cable is torsion balanced with the inner 2 layers in lay direction left and the outer layer in lay direction right.

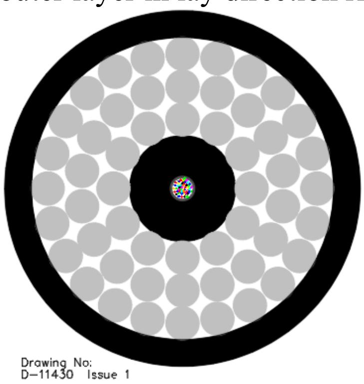

Figure 5: URC-1 RA (G48 QEVA R5/5/5)

Physical Characteristics	SAH	HA	RA
Outer Diameter (mm)	34	42	54
Cable Weight in Air (kg/m)	2.4	4.8	9.5
Cable Weight in Water (kg/m)	1.7	3.7	7.5
Minimum Breaking Load (kN)	> 280	>500	>1000
Nominal Transient Tensile Strength, NTTS (kN)	> 150	>300	> 600
Nominal Operating Tensile Strength, NOTS (kN)	> 100	>200	> 300
Nominal Permanent Tensile Strength, NPTS (kN)	> 50	>100	> 250
Minimum Recommended Bending at no load (m)	0.5	0.75	1.0
Minimum Recommended Bending above the NPTS load (m)	1.25	1.25	1.5
Operating Temperature Range (°C)	-10 to +40		
Storage Temperature Range (°C)	- 30 to +60		
Crush Resistance ,IEC 794-1-E3	> 25	> 40	> 40
Impact Resistance, IEC 794-1-E4	> 250	>400	> 400

Table 1. FO cable physical characteristics

The URC-1 cables are well protected against corrosion under normal seabed conditions, galvanized steel wires, surrounded by bitumen to increase the resistance against the corrosive environment. In special cases and in highly corrosive environments, other methods of corrosion protection can be implemented. The inner steel tube is a 100% encapsulating tube that protects the fibres from external forces and gas seepage.

2.1 CABLE ACCESSORIES/COMPONENTS

The submerged components Subsea URC-1 Joint, Branching Unit and Lay Down Head are primarily supplied in super duplex stainless steel which is resistant in seawater.

The Subsea URC-1 Joint box provide optical and mechanical continuity between contiguous cable sections and serve as repair joint. The joint box assembly is shown in Figure 6.

Figure 6: Subsea URC-1 Joint

The Branching Unit (BU) allows the connection of three different cables in a predetermined manner. The unit is a passive unit, meaning no re-routing can be accomplished from the terminal stations.
The BU consists of a 3-way branching unit body, including fibre joint housing and fibre service loops organizers. 3 off armour terminations with Bend stiffeners provide mechanical strength required for deployment and recovery of BU. The BU assembly is shown in Figure 7.

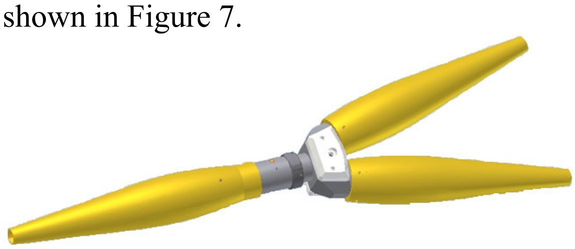

Figure 7: Branching Unit

The Lay Down Head have been used for cables ends that are laid on sea bottom for future expansions/connections. The Lay Down Head assembly is shown in Figure 8.

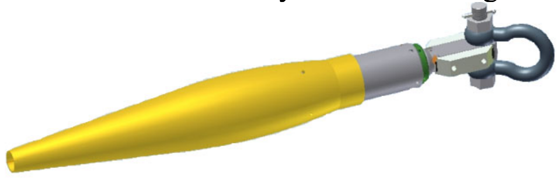

Figure 8: Lay Down Head

The submerged components are supplied in 25Cr duplex steel combined with xylan coating to the exterior surfaces of the components. 25Cr duplex steel as material is seawater resistant for temperature up to 25 degrees (C).

The coating of the components is either in xylan or painting, and sacrificial anodes in aluminium or zinc [6].

2.2 SYSTEM DESIGN LIFE EVALUATIONS

A high standard of reliability and stability was required during the lifetime of the system. Tampnet/NorSeaCom 1 installed in 1998 a submarine telecommunication cable system in the North Sea linking Norway and UK and connecting five offshore platforms. The system design was specified by NorSeaCom (later acquired by Tampnet to be minimum 25 years, and the Nexans submersible plant was designed for lasting at least 25 years life.

Nexans optical cables were first deployed in 1977. Thus, Nexans knowledge of the performance in the field is less than 40 yrs. Nexans track record on FO subsea cables goes back to 1986 with the installation of the first FO subsea cables along the Norwegian coast. Nexans have been delivering cables for subsea installation from 1989.
The experience from users like Tampnet shows that the design lifetime will be exceeded, and current experience shows that cables y have a lifetime above 30 years and estimates may be up to 50 years or more.
Nexans have also supplied a few FO subsea cables and FO elements for integration in subsea cables with specified design life of min 50 years [7].
The design life is of course not taking into account external damages (trawler boards, anchors, etc) and abrasive sea floors etc.
The main purpose of a submarine optical-fibre cable is to protect and preserve optical fibres for the system lifetime. This includes mechanical protection from forces experienced during installation and recovery operations, mechanical protection from hydrostatic pressure and chemical protection of the fibres.

3. CABLE INSTALLATION AND CONFIGURATION

The installation of the submarine fibre optical cables in the North Sea and other areas provide a cable owner with a lot of challenges.
First step is route selection, typically from point A to point B, and possible more route locations.

- A desktop study supported by good seabed data and even a marine survey if necessary.
- This information will lead to specific route selection, cable type, cable protection level and main part of the information needed by the cable installer.
- The desktop study also includes the use of BUs and cable tails (laydown head) for future use.
- In the North Sea the cables are installed in water depths ranging from 0 to 5-600 meters. (Other areas have water depth down to e.g. 4000 meters).

- Normally the cable in the North Sea is installed at a burial depth at 1 meter. This is normally sufficient for avoiding damage from repeated use of fishing gear.
- Typical installation of a cable is by use of seabed plough or water-jet trenching.
- Areas with specific protection requirements are typically suited with concrete mattresses or rock-dumping on top of the cable.

4. EXPERIENCE FROM THE NORTH SEA NETWORK

The installation of the submarine fibre optical cables in the North Sea has provided us with some experiences:

a) The use of Branching Units have been very useful in building up a robust meshed network.
b) BUs can be installed on a cable after the initial installation, making use of fibres and routing more flexible. However, cost is much lower if the BUs are installed initially.
c) Tampnet have experienced that the cable and the fibres inside the cables show limited degradation (corrosion/attenuation) after more than 20 years of operation buried in the seabed.
There was no visible corrosion on the galvanized steel wires in the cable armouring. The fibres measured were all below the initial requirement from 1998.
d) The submarine fibre optical cables can be relatively easy repaired if there is a cable break, typically effective repair time is 7-10 days depending on vessel availability and weather situation.
e) The North Sea Network was initially a simple network, but by the use of existing cables combined with new cables with Bus, it is now developed into a meshed Network. This network has become robust and can in most failure situations reroute traffic. This means that the availability for customers is very high.

5. CONCLUSION

Tampnet Un-repeatered cable system in the North Sea is a simple and sustainable system built up of simple components into a complex meshed network. Combined with optical switching technology available for rerouting, the users have a network that is reliable. The Network will last for years to come as the cables installed have increased the lifetime from 25 into 30 to 50 years.
Tampnet is proud to have a network that will be there for many years to come.

6. REFERENCES

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[4] IEC 60794 Optical Fibre Cables
[5] NxN-TR21-95 URC-1 Cable Qualification Report
[6] NxN-TR 127-15 URC-1 Cable Joint Qualification Report
[7] NxN-TR 25-01 Design Life Considerations for URC1 Submarine Cables

