The electro-optical cabling system for the NEMO Phase-2 tower

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Abstract

The cable system layout for the NEMO Phase-2 project has been studied starting from the experience obtained after NEMO Phase-1 deployment. The aim has been to improve the reliability and simplify the integration procedures of the system. This has been attained by reducing the number of optical fibers in the backbone and by an improved layout of the optical links in the cabling. Moreover an optimization in order to reduce the cost, in view of a large scale industrial production, has been performed. The design characteristics of the cabling system proposed for the detector line are presented.

Key words: NEMO km^3, electro-optical submarine cables, fiber optics, submarine seals
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1. NEMO Phase-2

The NEMO collaboration aim is the realization of a large volume neutrino detector in the Mediterranean Sea. A network of electro-optical cables will feed the electrical power to the sensors allowing at the same time the data transmission of the large amount of data collected. This paper focuses on the cable system for the NEMO Phase-2 project that will realize a 16 floors detector line. The cable system layout has been studied starting from the experience obtained after NEMO Phase-1 deployment (Migneco 2008; Capone 2008). The main aim has been to improve the reliability and simplify the integration procedures of the full scale system. This has been attained by reducing the number of optical fibers in the backbone and by an improved layout of the optical links in the cabling. Moreover an optimization in order to reduce the cost, in view of a large scale industrial production, has been performed. The design characteristics of the cabling system proposed for the detector line are presented.

2. Design Criteria

According to the philosophy of NEMO Phase-1 (NEMO 2008) the design criteria adopted during the definition of the cable system layout for the detector were:
- fault tolerance;
- simplicity;
- ease of assembly;
- ease of management;
- reasonable cost.

In order to realize a fault-tolerant system, the design should avoid the use of connectors at interface points since they represent single-point failure. Although a complex cable system requires the use of connectors to facilitate the assembly, their number should be minimized. Another relevant characteristic is the ease of management. It means that the system must be composed of separate and easy to test subsystems and easy to repair cables. Taking into account

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that the more interfaces a system has the more difficult is to perform tests, the goal is to minimize the connection interfaces. Moreover, a cable system for an underwater detector should be upgradeable to larger detector lines and manageable during the assembly. The use of penetrators should be preferred and connectors should only be placed at subsystem interfaces or where the assembly procedures impose their use. In order to have a fault-tolerant system the use of lightweight standard cables is another important aspect of the system design. This will reflect on the connector or penetrator layout and cost since a lightweight cable termination is simpler than an armored cable termination.

3. Detector line structure

The detector line for NEMO Phase-2, called tower (Musumeci 2006; NEMO 2008), is based on a modular structure composed by:
– aluminum alloy beams;
– retention ropes;
– buoys;
– protective oceanic devices;
– optical modules;
– instrumentation.
The aim of the beams (also called floors) is to maintain the positions of the optical modules and to host the instrumentation the Protective Oceanic Device (POD). The POD is made by an outer plastic container and and inner pressure vessel (PV) containing the electronics of the detector line. The retention ropes and the buoy are devoted to holding the beams in the operating position. The beams and the ropes offer a support for a lightweight electro-optical cable system. Moreover, the beams provide protection to the floor cable system that distributes power and signals to the detector sensors and instrumentation. The fact that the cable can be fastened to the retention ropes allows the use of a lightweight electro-optical cable since it is not under stress. This solution decouples the two issues of the mechanical and data-transmission cabling of the structure.

4. Design Optimization

The design of the full scale prototype of the detector line has required improvements of the NEMO Phase-1 cabling structure. The new cabling needed to be modular in order to simplify the integration procedures and to attain ease of handling of the parts to be assembled. The backbone has therefore been re-designed, the breakouts removed and their function has been incorporated into the PODs. In particular the mux-demux filters of the optical data transport network have been located inside the pressure vessels of the PODs. This new topology allowed for the removal of the costly and delicate electro-optical connectors from the backbone cabling. The absence of electro-optical connectors has also permitted to attain a reflection free optical and electrical path, offering an increased optical budget for the detector. This eases testing and monitoring during the detector life time. Further modifications have been introduced into base and floor cabling in order to reduce the impact of failures along the connections between the PV and the detector sensors and instruments. Point to point links have been introduced in almost all the cabling with the exception of the hydrophone connections. Using point to point links is helpful also because, for large volumes, it allows a great reduction of the manufacturing time of the harnesses of the cabling system.

5. Cabling breakdown structure and interfaces

The backbone cabling runs along the full length of the detector line, connecting the PODs in a chain-like topology. The floors PODs and tower base POD are connected to the backbone cabling by submarine joints. They assure an highly reliable interface between the PODs and the backbone cabling. Moreover the PODs are connected to the sensors and instrumentation by the floor cabling and base cabling subsystem (see Fig.1).

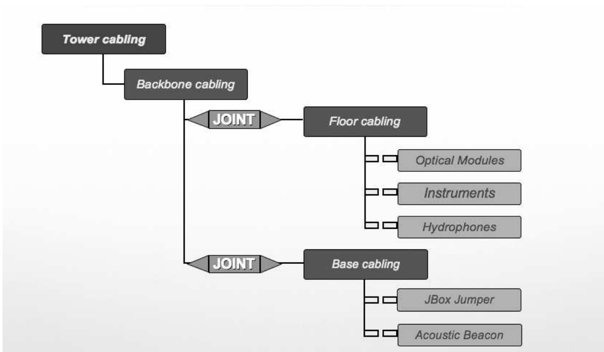

Fig. 1. Cabling system interfaces

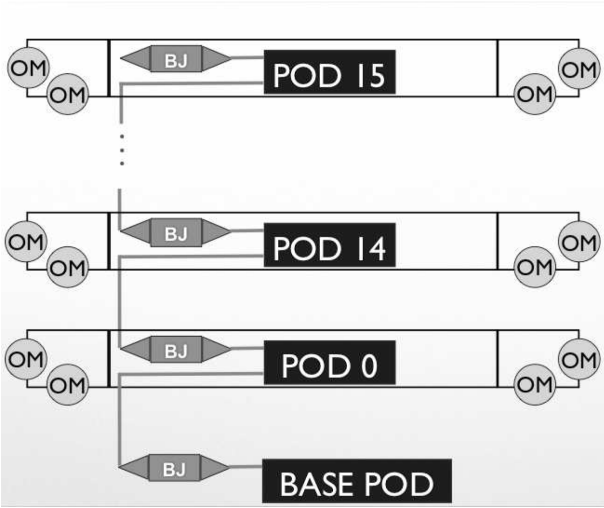

Fig. 2. Backbone cabling layout.

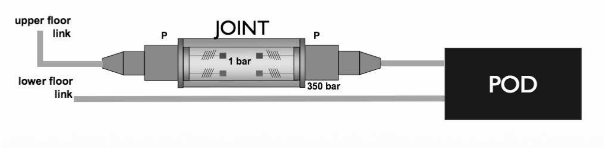

Fig. 3. Backbone joint.

5.1. *Backbone cabling*

The aim to deliver and distribute power and data transmission signals to and from the tower floors is assigned to the backbone cabling system (see Fig.2 and Fig.3).

The main compoments of the backbone cabling system are:
– electro-optical cable;
– electro-optical joints.

The cable is a lightweight standard type produced by Nexans (NEXANS2008) with five shielded twisted pairs (STP) and 12 single mode optical fibers in steel tube. The five STP are used for the DC power supply, control system and time calibration and 4 optical fibers are used by the data transport system. The cable is terminated with electro-optical penetrators on the joint side and on the POD side it is interfaced to the POD outer container with the feedthrough on which the STP wires are terminated by an electrical connector, while the fibers in steel tube proceed to the PV on which they are terminated by an optical penetrator. During the testing phases the fibers and the STP wires are terminated with standard bench connectors that are replaced by fusion splices and electrical joints during the integration phase, attaining a continuous optical and electrical link. After the assembly the PODs are equipped with two backbone sections. The short one is used to connect to the upper floor POD through joint positioned in the same floor and the long one is used to connect to the lower floor POD through the joint, positioned in the lower floor. Following this assembly, the floors can be stacked in modular fashion.

5.2. *base cabling*

The tower base hosts a dedicated POD interconnected to the backbone cable and to the ROV electro-optical connector. The ROV electro-optical connector is the interface between the tower and the rest of the underwater detector. The tower base POD is linked to the ROV connector using a custom submarine joint. One acoustic beacon is hosted in the tower base and it is connected to the tower base PV via a point to point link with terminal electrical connectors and feedthrough on the POD outer plastic container. The PV has five interfaces:
– two optical penetrators;
– three electrical connectors.

The two optical penetrators allow the link toward the backbone short cable to the upper floor POD and the ROV electro-optical connector. The electrical connectors are used for the acoustic beacon and the power supply module connection. The external plastic container has three interfaces:
– two hybrid feedthroughs;
– one electrical feedthrough.

The hybrid feedthroughs are positioned on the backbone cable link and on the ROV link. The electrical feedthrough is used for the beacon link of the acoustic positioning system.

5.3. *floor cabling*

The beam of each floor hosts one POD connected to the rest of the detector line by two backbone cables. Four oceanographic instruments are installed in the detector line: one doppler current meter, two transmissometers and one CTD . They are connected to the PV inside the POD via a point to point link with terminal electrical connectors and feedthrought on the POD outer plastic container. The PV has ten interfaces:
– two optical penetrators;
– eight electrical connectors.

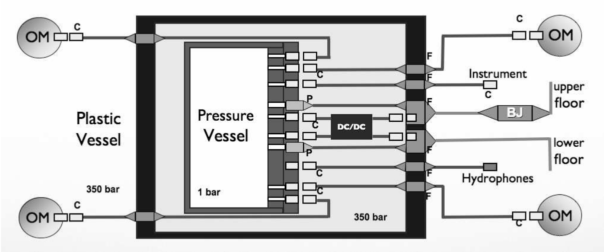

Fig. 4. Floor cabling layout.

The two optical penetrators allow the link toward the backbone short cable to the upper floor POD and the backbone long cable to the lower floor POD. The electrical connectors are used for the hydrophones, the oceanographic instrument, the four optical modules and power supply module connection. The external plastic container has eight interfaces:
– two hybrid feedthroughs;
– six electrical feedthroughs.
The hybrid feedthroughs are positioned on the backbone cable links. The electrical feedthroughs is are used for the hydrophones links of the acoustic positioning system, for the instrument and for the four optical modules (see Fig.4).

6. Conclusions

In the NEMO Phase-2 cabling system, the connectors will be positioned only at users interfaces. This allows to have few connectors reducing the cost of the apparatus and permits to individually test the single link in standard pressure tanks since their resulting sizes are relatively small compared to the full cabling system. Moreover, using penetrators instead of connectors minimizes the optical loss allowing a higher link budget for the data-transmission system and permitting to test the optical links by means of OTDR since there are no reflective interfaces along the optical paths. The usage of submarine backbone joint technique results in a high reliable backbone cabling, that is also modular and can be easily managed, handled and repaired during the integration phase.

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