The NeMO Project Status

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Abstract *The NeMO Collaboration, pursuing a cubic kilometre scale neutrino telescope in the Mediterranean Sea, is developing technical solutions for the construction of this challenging project, to be realized several kilometres below the sea level. The phase 2 of the project is currently under construction A general detector description will be presented with focus on: main electro-optical cable, deep sea power conversion, subsea power distribution network, connection systems issue.*

Keywords *Power system, Sea floor Network, Power converter, submarine cable*

1. INTRODUCTION

Starting from 1998 the NeMO collaboration has carried out R&D activities aimed at developing and validating key technologies for a cubic-kilometre scale underwater neutrino telescope [1]. The construction of this detector requires the solution of technological problems common to many deep submarine installations, and will help pave the way for other deep-sea research facilities. This challenging project detector is the result of evaluation based both on physics objectives, technical issues and costs and will require the installation of thousands of photon detectors with their related electronics and calibration systems several kilometres below sea level.
The R&D activities of the NeMO Collaboration consist of two successive phases to verify the technologies proposed for the cubic-kilometre detector. During NeMO Phase-1 [2] a junction box and a demonstrator tower was installed at a test site close to Catania at a depth of 2000 m.
The NEMO Phase-2 project, which is currently under construction, aims at installing an infrastructure, comprising a shore station, a 100 km electro-optical cable already deployed and a full scale tower, at the Capo Passero site at a depth of 3500 m.
For more than a decade, the feasibility of neutrino astronomy with a detector in the deep sea has been investigated in three pilot projects, ANTARES (based in La Seine sur Mere, France), NeMO (based in Catania and Capo Passero, Italy) and NESTOR (based in Pylos, Greece). In each of these, different configurations and techniques have been explored. These projects have provided a wealth of information on the technologies required for a large deep-sea neutrino telescope and constitute the KM3NeT consortium [3] [4]. In 2009 the KM3NeT consortium will publish the KM3NeT Technical Design Report (TDR)[5], detailing the most promising technologies and the expected physics performance of the future detector.
A site location located in a 3500 m deep abyssal plateau at approximately 40 NM south east of Capo Passero (36° 20' N; 16° 05' E) has been proposed by the NeMO collaboration for the installation of the km3 detector
In this paper, an outline of the present status of NeMO Phase 2 project with its main technological aspects will be presented with a particular focus on the main electro-optical cable, deep sea power conversion, subsea power distribution network and connection systems issue.

2. THE NEMO DETECTOR DESCRIPTION

Schematically the NeMO detector will consist of an array of vertical structures supporting optical sensors arranged to opportunely fill a volume of water of the order of at least one cubic- kilometer. The detector concept is based on semi-rigid vertical structures (towers), up to 800 m high. The tower is composed of a sequence of 20 horizontal structures (storeys), 12 m long, interlinked by a system of tensioning ropes arranged in such a way to force each storey to a position perpendicular to its vertical neighbours. The tower is anchored on the seabed. A buoy located at the top of the structure provides the force to keep the structure vertical and ensure its rigidity. The spacing between storeys is 40 m, while an additional spacing of 150 m is added between the anchor and the lowermost storey. Each storey hosts four optical modules, pressure resistant glass spheres containing photomultipliers (PMTs). The data from the PMTs in each storey are

collected by electronics located inside a suitable vessel placed on the storey. These data and the related control signals are transmitted to the base of the tower via a lightweight electro-optical cable backbone, mechanically separate from the system of tensioning ropes. The storey vessel contains also instrumentation for positioning and monitoring of environmental parameters and the power system.
The towers are connected through a network of undersea cables and junction boxes (JB) and a single main electro-optical cable to shore. The towers are connected to the junction boxes through underwater wet mateable electro-optical connectors operated by a remotely operated vehicle (ROV). The JB will host the power feeding system the control system and the data transmission system. Its main functions are to distribute the power from the shore to the towers, to monitor and control all the electrical parameters of the output lines, to remotely actuate the relays to switch on and off the feeding lines during normal operation, to detect a fault and automatically isolate a faulty line, to communicate to shore by means of optical fibers.

3. THE NEMO PHASE 2 INFRASTRUCTURE

In the last years both options, AC and DC power feeding systems, have been explored by the NeMO Collaboration with its prototypes [6]. Presently the design and realization of the DC power system of NeMO Phase 2 is completed. The NeMO Phase 2 infrastructure is in progress. It consist of a shore station, a main electro-optical cable, a full tower and a Frame Termination Assembly (FTA) A NeMO tower prototype will be connected to the frame to validate the proposed technologies of the project and to provide an on line monitoring of the site.
The Power Feeding Equipment and the main electro-optical cable have been already installed and are able to feed a 50 kW load. The Frame Termination Assembly is now ready to be deployed. The tower is under realization.

3.1 On Shore Power Feeding Equipment

The on Shore Power Feeding Equipment, (PFE), is composed by an AC/DC converter. The PFE provides 50 kW at 10 kV DC with sea current return. The PFE is realized from HEINZINGER Electronic GmbH. The main characteristics are reported in Table 1

Table 1. Power feeding equipement characteristics

Input	3 phase 400 V
Power Factor	> 0.9
Output Voltage	
Negative Polarity	0 to 10 kV
Positive Polarity	0 to +1.5 kV
Regulation	< 0.1 %
Output Voltage Noise	< 1 V RMS <10 V_{pp}
Output Current	
Negative Polarity	5 Amp
Positive Polarity	1.4 Amp
Output Current Noise	< 10 mA RMS

3.2 The Main Electro-optical Cable

The main electro-optical cable has been manufactured by Alcatel [7] [8], Fig.1. It carries a single electrical conductor, that can be operated up to 10 kV DC, and 20 single mode ITU-T G655 optical fibres for data transmission. The cable total length is about 100 km. The submarine cable was deployed in July 2007.

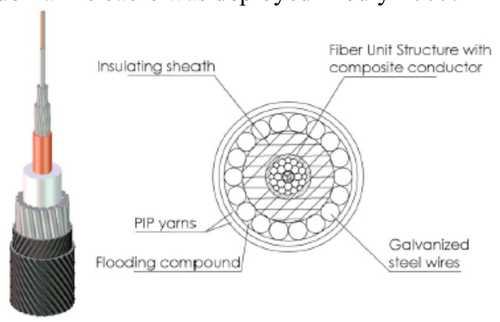

Fig. 1. Main electro-optical cable

3.3 Frame Termination Assembly

At the end of the submarine cable there is a Frame Termination Assembly that hosts:

- the Cable termination Assembly (CTA), that permit to split power and fiber optics,
- the Medium Voltage Converter (MVC),
- the Splitting Box with three output wet-mateable connectors.

All these elements have been tested separately and have been mounted in the FTA, Fig. 2.

3.4 The Medium Voltage Converter

The MVC provided by Alcatel converts the 10 kV to an instrument-friendly 375 V with 10kW capacity. The MVC is built from a number of low power sub-converters blocks arranged in a series-parallel configuration to share the load and provide redundancy.

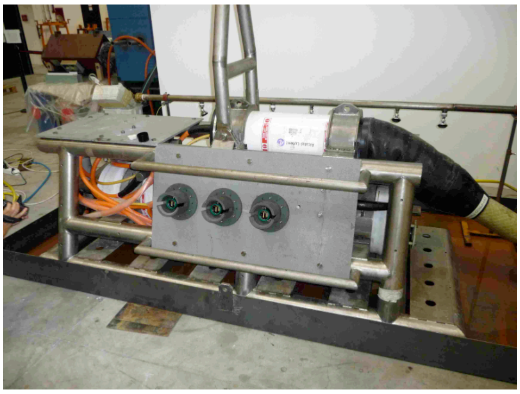

Fig. 2. Frame Termination Assembly ready to be deployed

The converter configuration is made of 48 power sub-converter grouped in 6 blocks (stacks), Fig. 3 arranged as matrix of 6 parallel legs with 8 sub-converters in series in each block. This arrangement allows for faults without a failure of the full converter. The estimated efficiency is greater than 85% at full load.

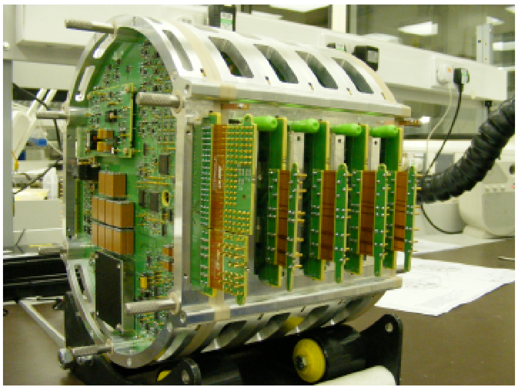

Fig. 3. Stack of a Medium Voltage Converter

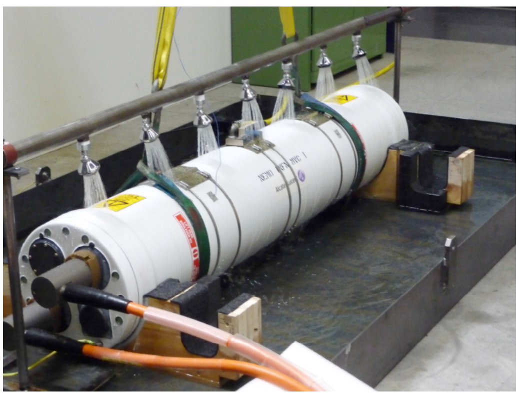

Fig. 4. Medium Voltage Converter under test

The power converter is housed in a pressure vessel, Fig.4, filled with Fluorinert to facilitate the cooling and reduce voltage clearances.
After several years of design, development, assembly and testing, two units are ready and undergone the Factory Acceptance Tests in July 2009. Several tests have been carried out in the last years to verify the functionality and performance of the MVC in particular working conditions: long feeding lines from the 10 kV power supply to the MVC (100 km), long interconnecting cables of the MVC output with the electrical loads and distributed switching DC/DC converters as electrical loads.
The results of the tests were positive as the MVC worked properly without causing any oscillation or instability in the system. The main characteristics of the NeMO MVC are showed in Table 2.

Table 2. Medium Voltage Converter characteristics

Input Voltage	5,7 ÷ 10 kV
Output Voltage	375 V
Output current	25 A
Input shut down voltage	5,2 kV
Efficency@6kV full load	88,9%
Efficency@10kV full load	85,4%
Voltage undershoot@10kV -10% to 90% step up	40 V
Voltage overshoot@10kV -90% to 10% step down	43V
Output Ripple Voltage	1,5 Vrms @ 100 kHz

4.CONNECTING SYSTEMS

The design requirements, in terms of power distribution, data transmission system and interlink connection, for an ocean observatory site-to-shore cable are compatible with the standard capabilities of telecommunications cables, for which a wide range of industry-approved standard, connection boxes, couplings and penetrators exist, which can be adapted to interface with scientific equipment. Underwater connection systems technologies, available from telecommunication and oil and gas market, including deep-sea wet-mateable optical, electro-optical and hybrid electro-optic connectors, have been adapted and developed to fulfil the project requirements. Such issues present particular challenges when there is a practical need for wet-mate connectivity. Technical challenges associated with seabed observatories include: water dept (down to

4,500 meters), high voltages (10 kV DC) and high bandwidth. The desire to bring real-time science data from individual experiments directly back to the shore drives up bandwidth requirements of several Gbit/sec. During the last two decades the wet-mate connectivity added the benefit of re-configurability and maintainability on the seafloor with the use of Remotely Operated Vehicles (ROVs). Prior to this time, cabled systems were hard-wired and required the system to be harvested from the seafloor for maintenance or re-configuration. In this scenario a new 10 kV electrical wet mateable connectors under development by Ocean Design will open knew possibilities in the design of subsea power distribution networks, Fig.5.

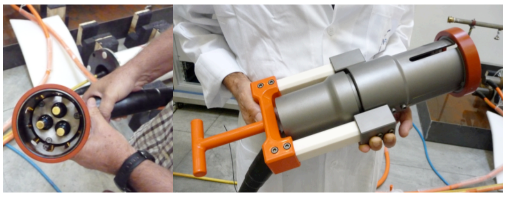

Fig. 5. Ocean Design 10 kV wet mateable connector

4. CONCLUSIONS

An underwater infrastructure is under realization on the deep sea site selected by the NeMO collaboration as a candidate for the installation of the km^3 neutrino telescope. The infrastructure includes a 100 km long electro-optical cable, a shore station in Portopalo di Capo Passero and the power feeding and control equipments.

The main electro-optical cable is already deployed, the on-shore power system has been installed, the cable termination and a specially developed Medium Voltage Converter have been tested and integrated in a frame and are ready for the deployment that will take place before the end of 2009.

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