The
CAPO PASSERO
Infrastructure

The km3-IT collaboration

ABSTRACT

This report is intended to describe the technical details of the on shore infrastructure and submarine network in Capo Passero and to provide an internal documentation tool for communication within the KM3 collaboration.
The Italian km3net site, situated 100 km off the Sicilian SE cost at 3500 m depth was selected both for environmental and logistic reasons. It is already connected to the shore station with an electro optical cable and since March 2013 it is continuously monitored with a prototype detection unit, an 8 floors tower .
This document describes the present status of the infrastructure, the characteristic of the site and the design of the upgrade necessary to allow the connection and maintenance of the first planned batch of 32 detection units: KM3NET Phase-1

Contents

1.The present facility in Capo Passero

The onshore infrastructure at Capo Passero was realized in 2010 in a restored old wine cantine close to the small harbor of Portopalo in the southeast extremity of Sicilian coast. The power station, located in a conditioned room inside the building, directly feeds the main 100km long electro optical cable deployed in 2008 down to the 3500m depth of the site together with the termination frame. This termination includes a DC/DC converter and 3 wet mate hybrid (electro, optical) connectors where in April 2013 a first detection unit prototype , an 8 floors tower, was plugged.

1.1 The building

The building hosts various rooms to operate the detector, an upper floor to provide space and lodging for onsite personnel while a separate room is dedicated to the power station.
The shore station is connected to the external electrical supply for a total power up to 800 kVA. The cooling system is mostly dedicated to the conditioning of the room where the power supply of the cable is located. The uninterruptible power supply (UPS) is dimensioned to feed up to 150 kVA.
The rooms dedicated to the operation of the detector includes one room for the racks of the read out and clock system of the detection unit, the PCs for the online trigger and data filtering while a separate control room hosts various monitors for the apparatus control and status monitoring.
The local network is used for data acquisition, monitoring and control systems and it is connected to the INFN Laboratori del Sud in Catania via a fibre connection at 1 Gbps both for data transmission and remote control of the apparatus. This communication is inserted inside the GARR-X network, the multiservice communication network dedicated to the Italian University and research community.

Fig. 1.1 The external view of the shore station

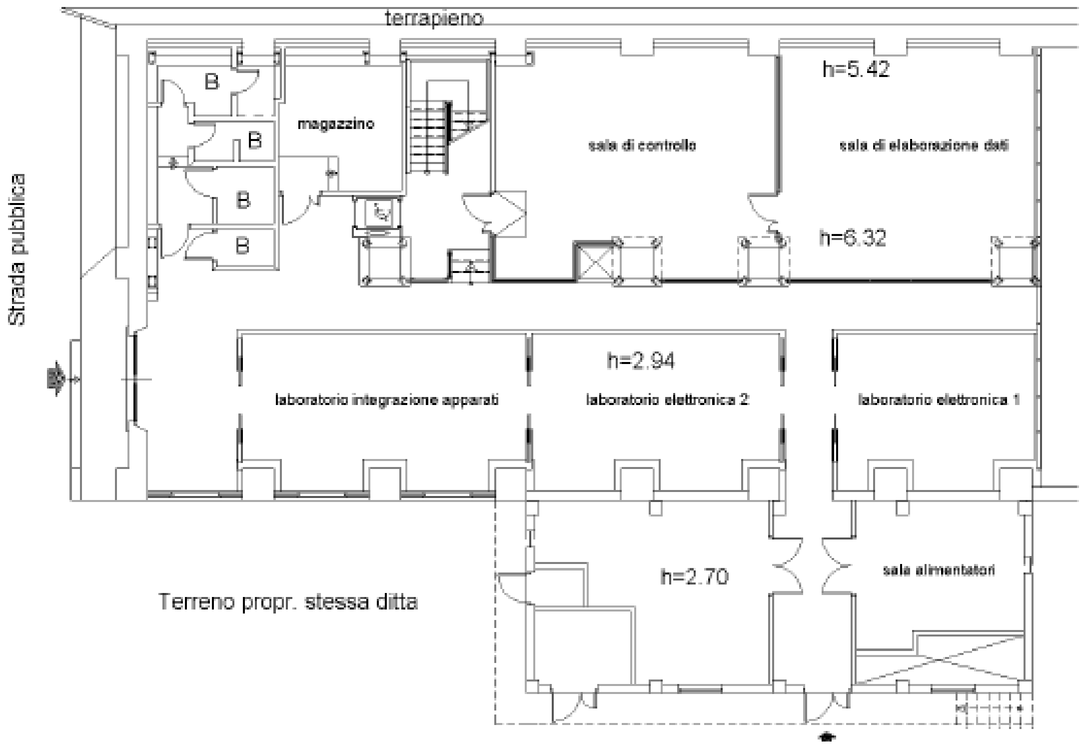

Fig.1.2 The ground floor of the Shore station

1.2 The power system

The power transmission system consists on a shore based Power Feeding Equipment (PFE) protected by an UPS, a Main Electro Optical Cable (MEOC) operating at 10 kV DC with one power conductor, the return current being led through the seawater. At the end of the MEOC the 10 kV DC is stepped down to 375 V DC to supply the detection units. This is done using a Medium Voltage Converter (MVC).
The main elements of the power system, see Fig. 1.3 are:

On-Shore:

- Uninterruptible Power Supply (UPS)
- Power Feeding Equipment (PFE) with 10kV DC output voltage

Off-Shore:

- Main Electro-Optical cable (MEOC)
  - Max length 100km
  - Max depth 3500 m
  - One copper conductor with sea return
  - Optical fibers G.655
- Sea Earth
- Cable Termination Frame (CTF)
- Medium Voltage Converter (MVC)

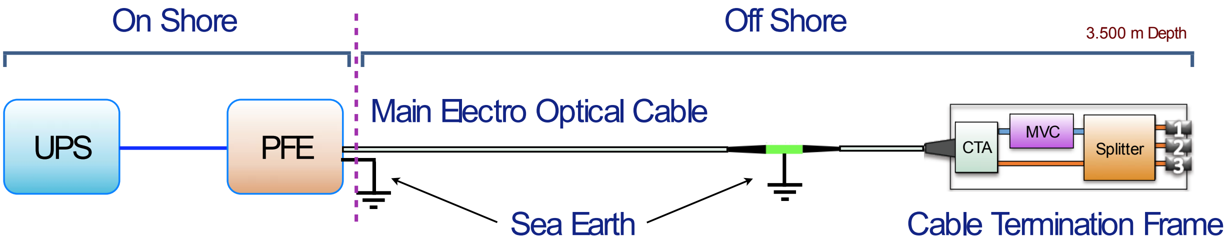

Fig. 1.3 The Power System.

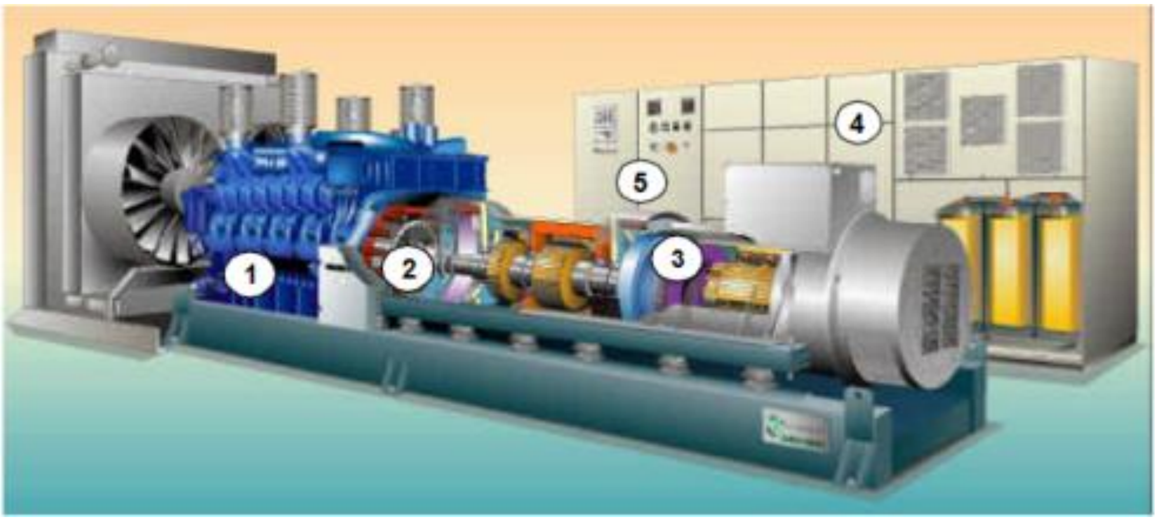

Fig.1.4 The UPS

1.2.1 The UPS

To prevent damage to the PFE and to the backbone cable an on line UPS Motor Diesel Type 150 kVA total power was installed.
The main components, as shown in Fig.1.4, are the following:

1) Diesel engine;
2) Electromagnetic brushless clutch;
3) A special brushless rotating machine, called a "stato-alternator", composed of:
   - synchronous alternator
   - kinetic energy accumulator with single excitation
4) A power cabinet containing the motorized breaker units and an inductance;
5) A control panel and the dedicated electronic circuit boards to control and monitor operations.

1.2.2 The PFE

The PFE fromHeinzinger electronic GmbH, draws 400 V, 50 Hz AC power from the electricity grid and is based on a high precision, high performance power supplies system with a precisely controlled DC voltage at minimum ripple. The PFE, shown in Fig.1.5, is located in a dedicated room, air conditioned, of the shore station.

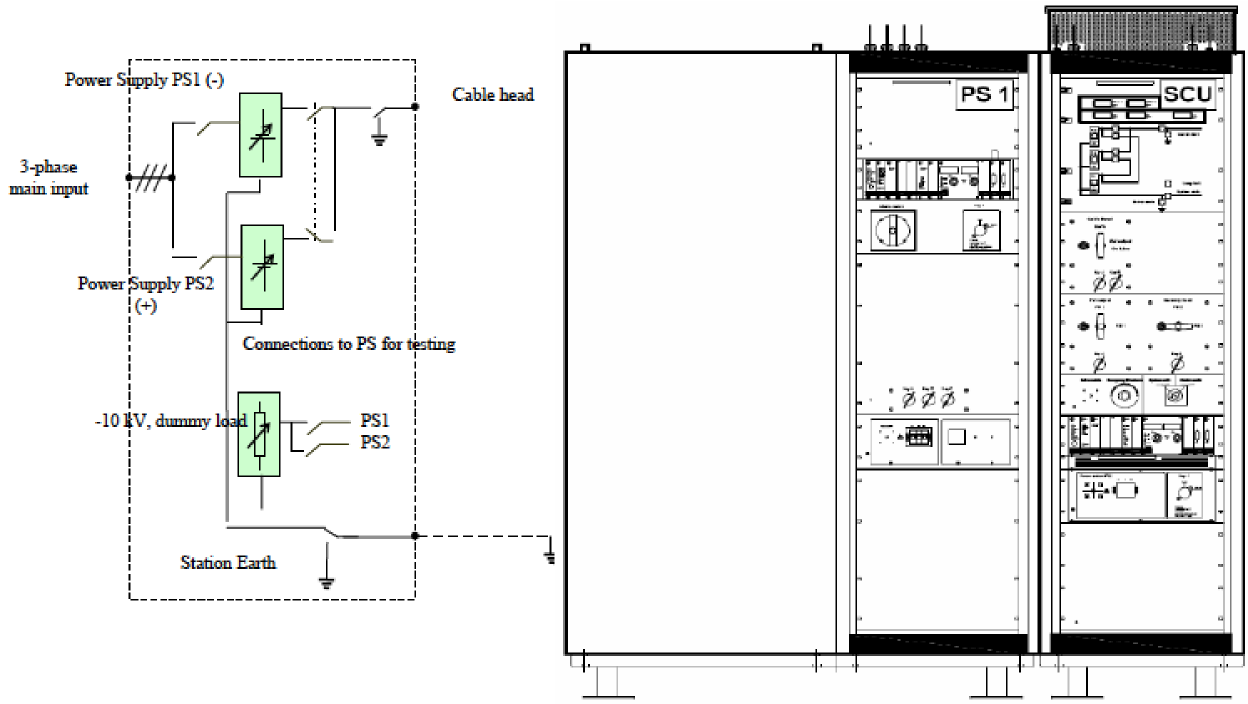

Fig. 1.5. The Power Feeding Equipment

The PFE includes :

- The principal Power Supply (PS1)
- A 1.5 kV Positive power supply (PS2) to be used for possible future extensions
- A 20 kOhm dummy load to tests PS1 or PS2
- A switch matrix to connect PS1, PS2 to the cable head or dummy load
- Manual switches enabled by safety keys to connect the cable head to the HV power supplies or to earth.

Main Characteristics of Power Supply 1:

- Output voltage: 0 ... 10,000 V DC
- Output current: 0 ... 5 A
- Output polarity: negative
- Max output power: 50 kWatt
- Input voltage: 400V / 50Hz
- 3 phases + protection earth
- Configuration Voltage: 400 V / 50 Hz
- Nominal input current: 95 A
- Maximum input current: 110 A

Switch control unit (SCU), consisting of:

- Main machine interface to control the setting of different operation modes
- Displays for voltage and current values of the HV System
- Cable Head and Earth switches
- Dummy load, 10kV, 5kW

Power Supply 2

- Programmable and regulated power supply
- Output voltage: 0 ... 1,500 V DC
- Output current: 0 ... 1.4 A
- Output polarity: positive

- Configuration Voltage: 400 V / 50 Hz
- Nominal input current: 5.0 A
- Maximum input current: 6 A

The principle of the dual control power supplies is based on the combination of two control loops. Pre-stabilization by a phase angle control circuit supplies a buffer, a succeeding, fast linear transistor controller provides fine stabilization. In this way, precise compensation of load or mains variations can be achieved in conjunction with high efficiency and excellent long term stability.
cases.
During normal operation the system uses PS1 connected to the cable head. PS1 output power can be adjusted with 2 independent settings. The nominal voltage of the system may be adjusted between 0 and 10 kV, the recommended operating range of the MVC being between 6.5 kV and 10 kV to be able to deliver the full power. The maximum current (current limit) can be adjusted between zero and 5 Amp. If a short circuit occurs in the system, the PFE will automatically limit the current to the voltage dependant current limitation as in Fig. 1.6 below. This to prevent unnecessary excessive current to flow in the system. The PS1 power supply output voltage variation is controlled during power up by an internal fixed ramp of 100 V/ second.

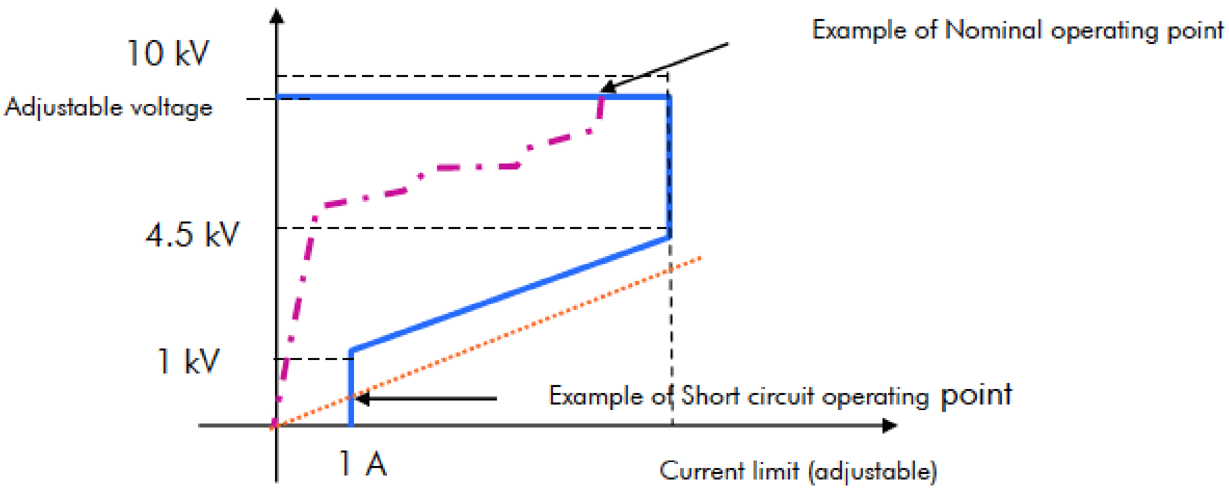

Fig. 1.6. Power supply current limitation

1.3 The main electro optical cable

The design requirements for an ocean observatory cable, where data and power are to be delivered and distributed about a submerged network, are very compatible with the standard capabilities of telecommunication cables. As it is normal industry practice, all of these cables have proven and qualified couplings and penetrators for connection to underwater equipment based on designs with more than ten thousand cumulative operating years before failure. These can be readily adapted to interface with a wide range of scientific equipment. The KM3NeT main electro-optical cables is a standard submarine telecommunication cable. The submarine electro-optical cable chosen for the experiment is Alcatel mod. OALC – 4 17 mm Type 30, with different protection armouring, shown in Fig. 1.7. This standard submarine cable configuration is a single conductor power transmission system with current return via the seawater. The extremely small resistance of the sea return also implies a system with lower power losses. Such systems incorporate sea electrodes both at the shore and in the deep sea as shown in fig. 1.8

Fig.1.7: different armouring in the main cable

Length [km]	100
Type of power to be transmitted	DC, sea return
Maximum Voltage [kV]	10
Maximum Nominal Current [A]	8
Cable resistance [Ω/km]	1-1.6
Number of fibres	20

Table 1: Main Electro-Optical Cable characteristics

The backbone cable conductor is connected to the negative terminal of the Shore PFE and the electrode is connected to the positive terminal of the CTF. This polarity is used to minimize consumption of the remote seafloor electrodes (cathodes) that are difficult to maintain. The shore electrode (anode) is consumed but this can be made arbitrarily large and can be maintained/replaced, if necessary.
The 20 optic fibres in the MEOC are Corning Vascade LEAF negative dispersion NZ-DSF and their characteristics are shown in the following table 2:

	Name		ASN Reference	
Fibre	G655 RS		B009D7	
	UNITS	NOMINAL	MIN	MAX
Attenuation	dB/km			0.23
Chromatic Dispersion	ps/nm/Km		- 4.2	- 1.6
Chromatic Dispersion Slope	ps/nm^2/km	0.06	0.05	0.07
Polarisation Mode Dispersion	ps/√km			0.2
Effective area	μmm^2	70		

Table 2: Main Electro-Optical Cable Fibers characteristics

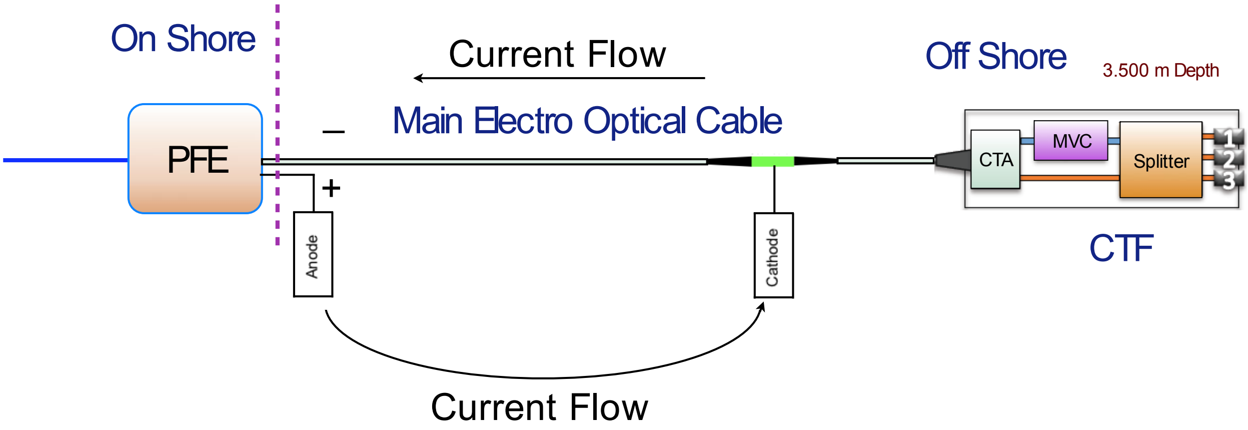

Fig. 1.8: Power Circuit showing Current Return Electrodes

1.4 The cable termination frame

1.4.1 Description, general layout

The Cable Termination Frame (CTF) is composed of the following parts as shown on the Fig.1.8:

- Cable Termination Assembly (CTA)
- Medium Voltage Converter (MVC)
- Splitter box

The CTF distribute power and communication to the submarine network. It is linked to the MEOC via the Cable Termination Assembly (CTA) and converts the supplied medium voltage (-10 kV DC) to an intermediate voltage (375V DC). The intermediate voltage is distributed to 3 output ports that can be connected underwater by ROV wet mateable connectors. Similarly fibres optic communication is distributed to the same output ports. The Cable Termination Assembly is a device that permit to split power and fibers as shown in Fig. 1.9- In this configuration only 8 out of the 20 optic fibres of the cable are unfolded and distributed to three outputs.

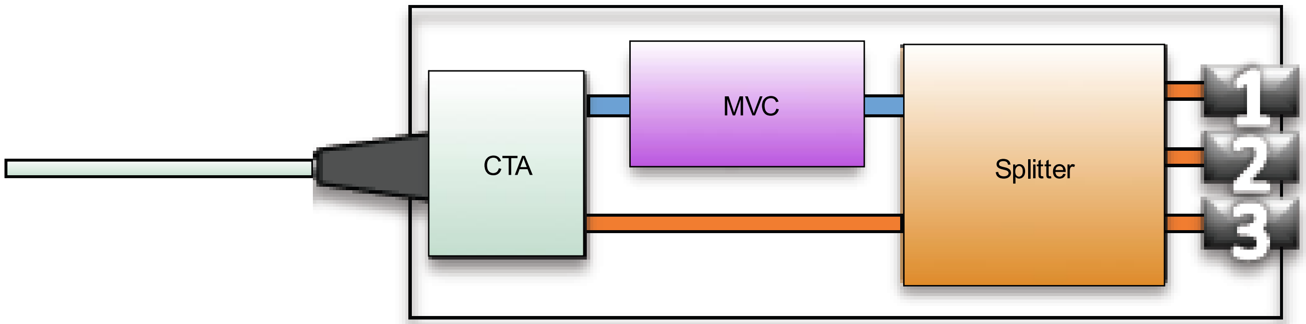

Fig. 1.8: the cable termination frame

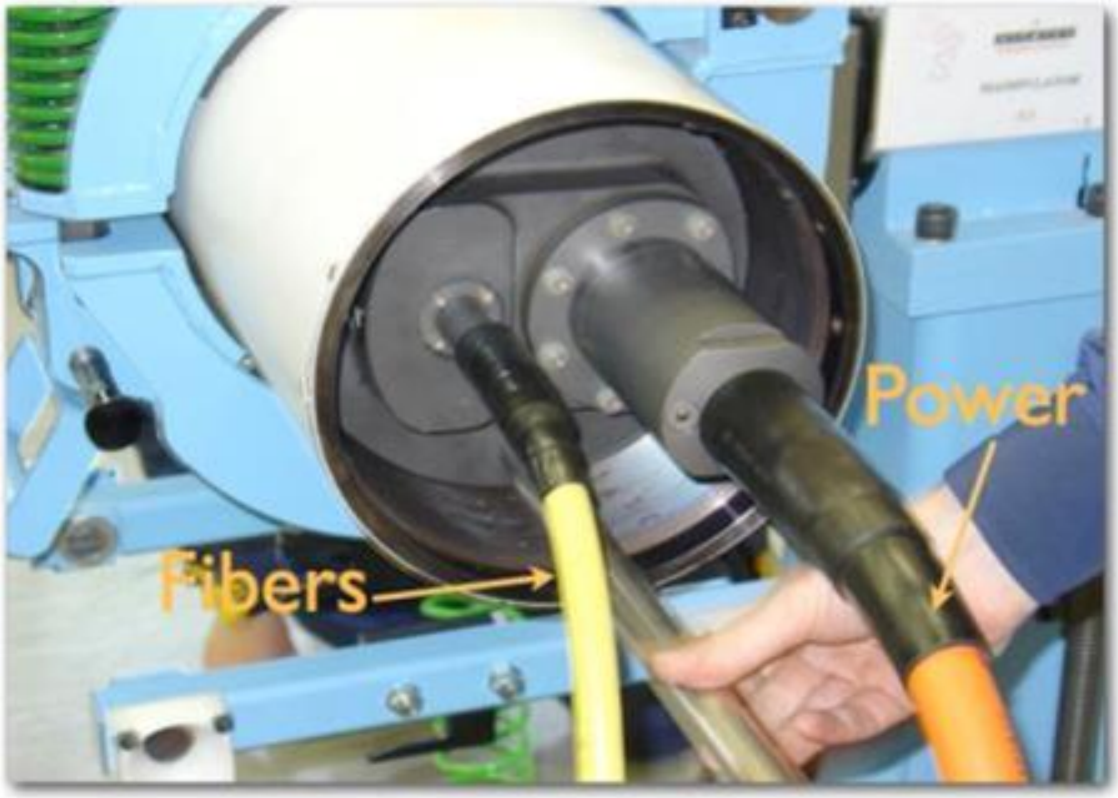

Fig. 1.9: the Cable termination assembly

1.4.2 The Medium Voltage Converter

The 10 kV DC is stepped down to 375 V DC to supply the detection units. This is done using a Medium Voltage Converter (MVC) provided by ALCATEL.

The converter is configured as a matrix of 48 power converter building blocks (PCBB) arranged in 6 columns connected in parallel, each having 8 blocks in series as shown in Fig. 8. This arrangement allows for the converter to continue operating, even with some faults in the printed circuit boards. Each building block is a pulse width modulated switching forward converter with an input of 200 V and an output of 50 V. Each block has four MOSFETs, two working as a primary switch and two on the secondary side as a synchronous rectifier. A block diagram of the circuit is shown in Fig.1.10. The various transformers are able to withstand continuous 10kV operation.

The physical construction is shown in Fig 10, it shows PCBBs on 13 PCB's and a bellows unit to control pressure. The converter pressure vessel will be filled with a dielectric fluid to allow good cooling and reduce voltage clearances. A start up circuit takes a small amount of power from the -10kV input to start the gate drive, once working its supply is taken from the PCBB output stage. The overall specification is as follows.

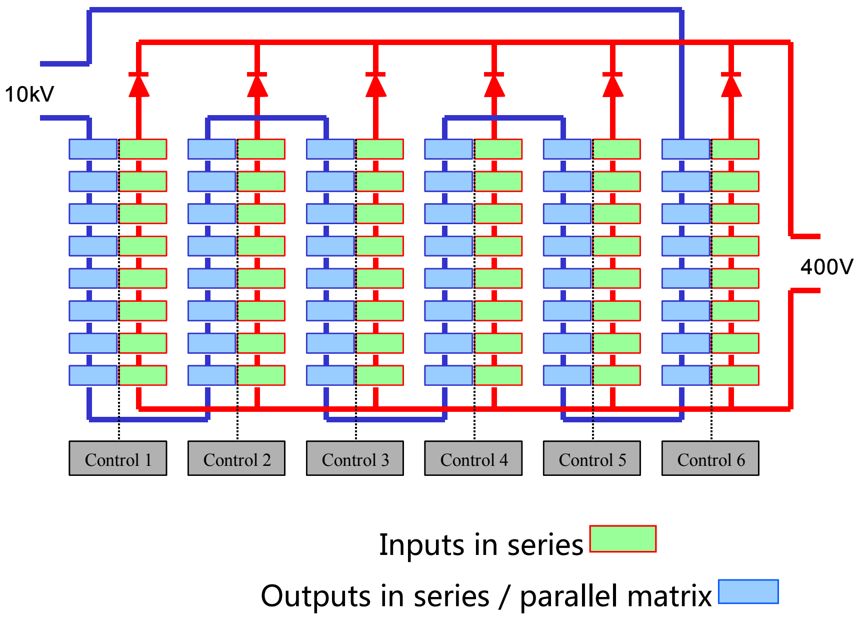

Fig. 1.10 Building blocks of the medium converter

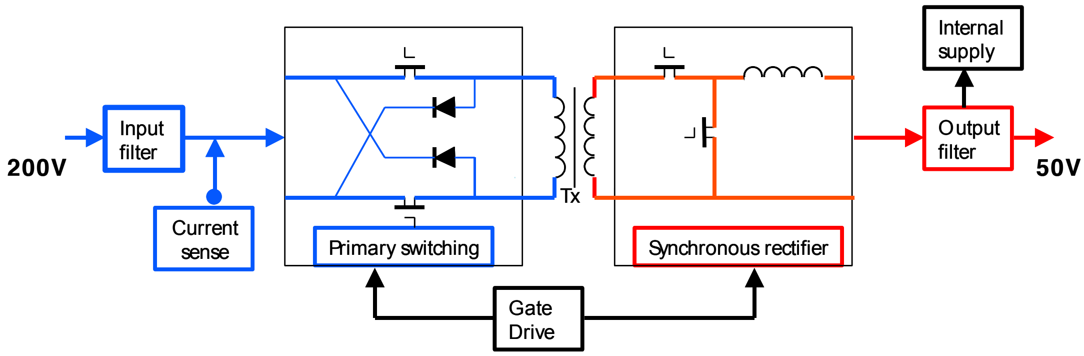

Fig. 1.11. PCBB Sub-Converter

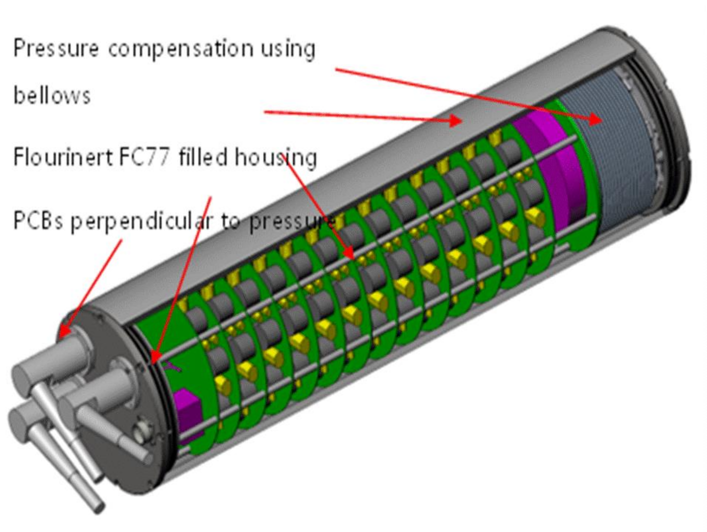

Fig. 1.12. The external layout of the MVC

The specifications of the MVC are the following:

- Input voltage: DC 0 -10 kV
- Normal Operation Input Voltage Range: -5,7 kV to -10 kV
- Input Voltage Shut down: -5,2 kV
- Voltage Output: 375 V
- Current Output: 26,5 A
- Regulation topology: PWM
- Step Load Variation: 10% to 90% -10% V_{out}
- Step Load Variation: 90% to 10% +10% V_{out}
- External Vessel Working Temperature: +13 °C
- External Pressure Vessel: 350 ÷ 400 Bar

The MVC hosts two connectors for the power input and output, both water mate . The input connector is an ODI Inc. Power type 10 kV as shown in Fig. 1.13. The Output connector is an ODI Inc. NSD ROV type with 6 electrical conductors.

Fig.1.13: the Ocean Design 10 kVolt connector

The present splitting box, shown at Fig. 1.14, realized by Ocean Design Inc., permit to split the 375 VDC and fibers optics to the 3 wet mateable ROV connectors as shown at Fig. 1.15. The wiring configuration of the three output connectors P1,P2 and P3 is shown in fig.1.15. While the electrical pins 5, 6 are obviously common to all the 3 ouputs, there are two optic fibers in P1 and 3 in P2 and P3.

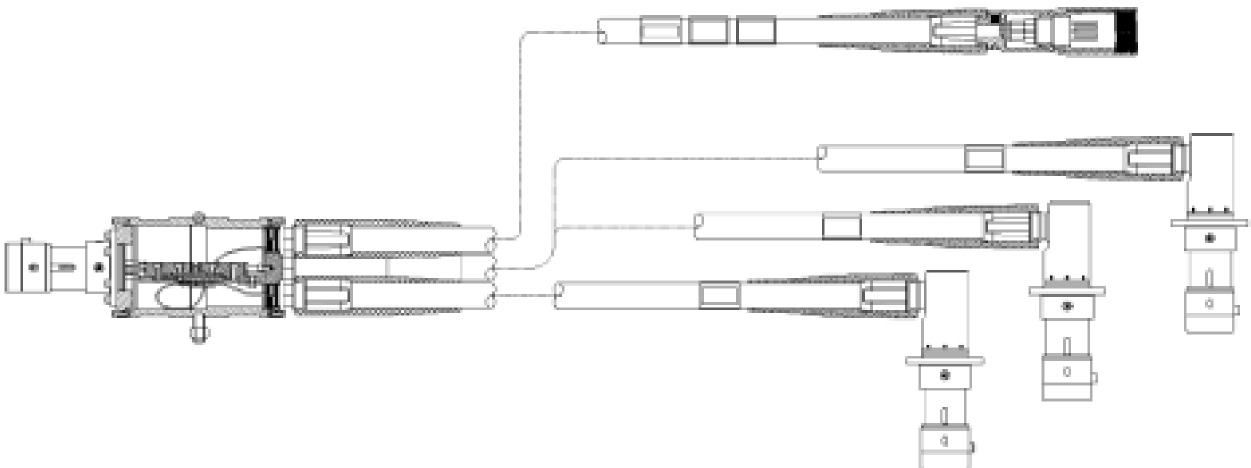

Fig. 1.14 The splitting box

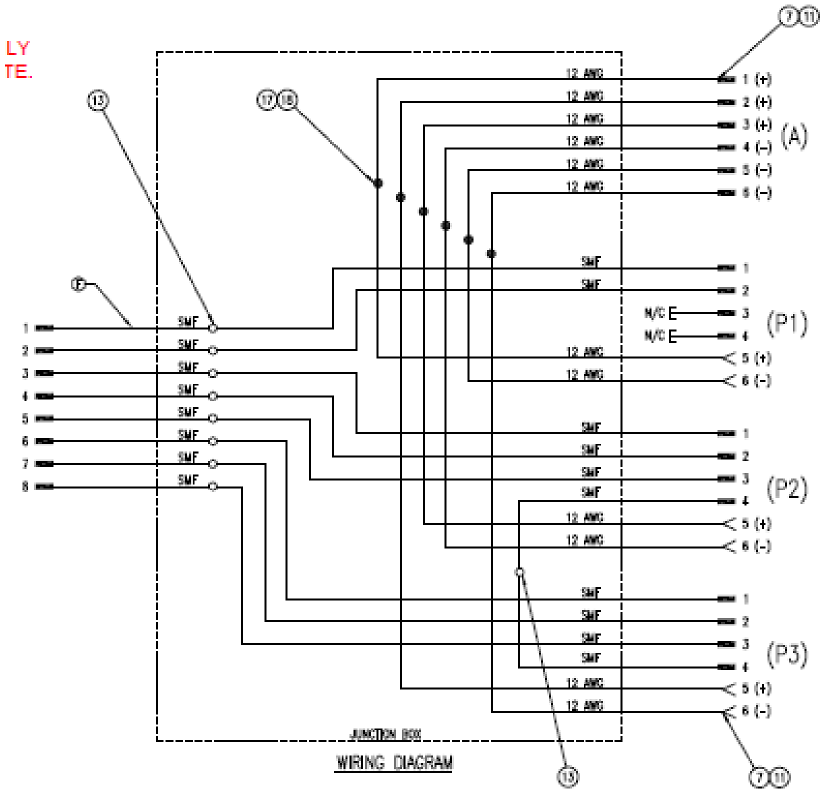

Fig. 1.15: The unfolding of the 8 optic fibers (left) to the3 CTF outputs

Fig. 1.15: the 3 ROV mate connectors in the front panel of the CTF

2. The site

The NEMO Collaboration has performed, since 1998, a long term research program to select and characterize a deep-sea site that could be appropriate for the installation of a high-energy neutrino detector. A series of campaigns to study and to monitor the most important environmental parameters was carried on in three sites close to the Italian coast. The long term characterization of the sites has been performed by studying a large number of oceanographical properties, like deep-sea water optical properties (absorption and diffusion), water environmental properties (temperature, salinity), biological activity, optical background, water currents, sedimentation and seabed nature. This activity has demonstrated that a site in the Ionian Sea close to the southernmost cape of the coast of Sicily (Capo Passero) with a depth of about 3500 shows excellent characteristics to host the km3 underwater neutrino detector.

2.1 Previous measurements and the choice of the site

The three sites were selected according to the geographical constraints of depth, proximity to the coast and nature of the seabed .
The sites, shown in fig. 2.1, are:

- Capo Passero, located in the Ionian Sea South-East of Sicily at 36° 16' N, 16° 06' E, about 40 NM from the coast, with a depth of 3350 m;
- Ustica, located in the Tyrrhenian Sea North of Sicily at at 38° 55' N, 13° 18' E, about 15 NM from the coast, with a depth of 3500 m;
- Alicudi, located in the Tyrrhenian Sea North of Sicily at at 38° 56' N, 14° 16' E, about 25 NM from the coast, with a depth of 3500 m;

The characterization of the sites includes the study of optical properties of the water which are important and requires long term measurements in different periods of the year to evidence possible seasonal dependences.

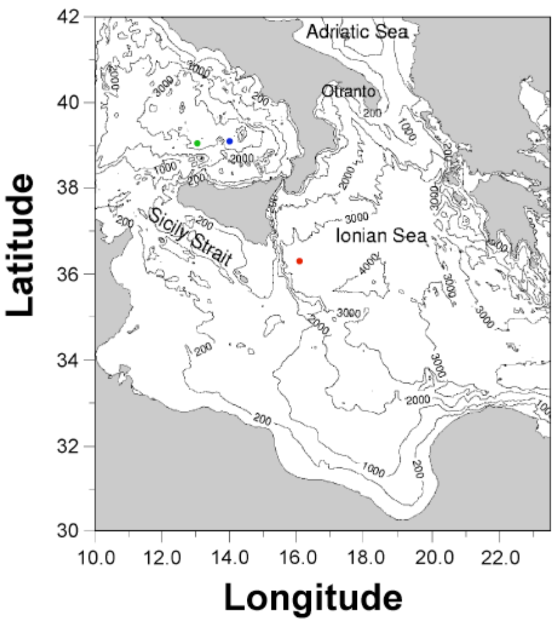

Fig.2.1 Bathymetry of the central Mediterranean region. The sites explored by the NEMO collaboration are shown in dots: Capo Passero (red), Ustica (green), Alicudi (blue)

Optical background noise in the detector comes mainly from two natural causes: the decay of ^{40}K, which is present in seawater, and the so called "bioluminescence" that is the light production by biological entities (bacteria or larger size organisms).

Another important parameter is the deep sea current that have been continuously monitored in Capo Passero since 1998. The analysis points out that the behaviour of the deep sea currents in the area is almost homogeneous on the part of the water column that has been monitored (bottom 500 m) with very low average values (around 3 cm/s) and peaks not exceeding 12 cm/s.
The study of the downward flux of sediments yields alternative and quantitative information about the suspended matter in deep sea waters. This parameter together with the nature and structure of the seabed was investigated in detail and was taken in account during the design the mooring structures of the neutrino detector. The flatness and the absence of any evidence of recent turbidity events, which occur when sediments of the continental shelf slide down the continental slope was also established.
From these measurements and from other considerations based on oceanographical properties of the Ionian region from the literature, we arrived at the decision that a large region close to Capo Passero (figure 2.1) is appropriate for the construction of the Neutrino Telescope. Therefore, our research effort in the following has been concentrated in this area.
The selected site presents also the advantage of being close to well-equipped shore infrastructures:

- the ports of Malta and Catania;
- the international airport of Catania;
- the I.N.F.N. Laboratori Nazionali del Sud in Catania.

Once Capo Passero was selected, the collaboration started a series of campaigns aiming to study the long term behaviour of optical properties. In particular three campaigns were performed during 2002 (March, May and August), in order to verify the occurrence of seasonal effects in optical properties. It is expected, in fact, that during the periods of major biological activity (like springtime) the concentration of dissolved and suspended particulate increases, worsening water transparency.
As an example the absorption length, averaged for depths greater than 2850 m, is shown, as a function of the wave length, in figure 2.2. There is no evidence of a seasonal dependence of the optical parameters. We can therefore conclude that optical properties in Capo Passero are constant over the year.

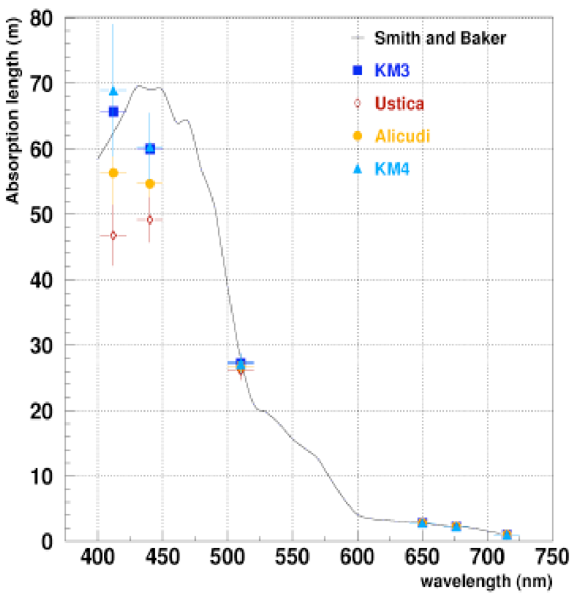

Fig. 2.2: Comparison between average absorption lengths, measured at depths greater than 2850m, in the two Capo Passero sites (KM3,KM4), Alicudi and Ustica (December 1999). The curve relative to optically pure water is plotted in black

On March 2013, the first detection unit, an 8 floors tower, was deployment in the site and since then the bioluminescence activity was continuously monitored using the hits recorded by the8x4 PMTs of the tower.

Fig. 2.3 represents, for the April-July 2013 period, the average rate in kHz of the single events (hits above 0.25 photo electron threshold) recorded in one of the four optical modules of each floor , PMT1, for the 8 floors separated by 40m.

These values are in the range of 50-60 kHz for all floors i.e. on a water column of 100+ 7x40 =380 m height . This rate almost corresponds to the expected contribution from the 40K decays in water. The peaks above this baseline are due to the bioluminescence activity which seems very modest during the monitored period

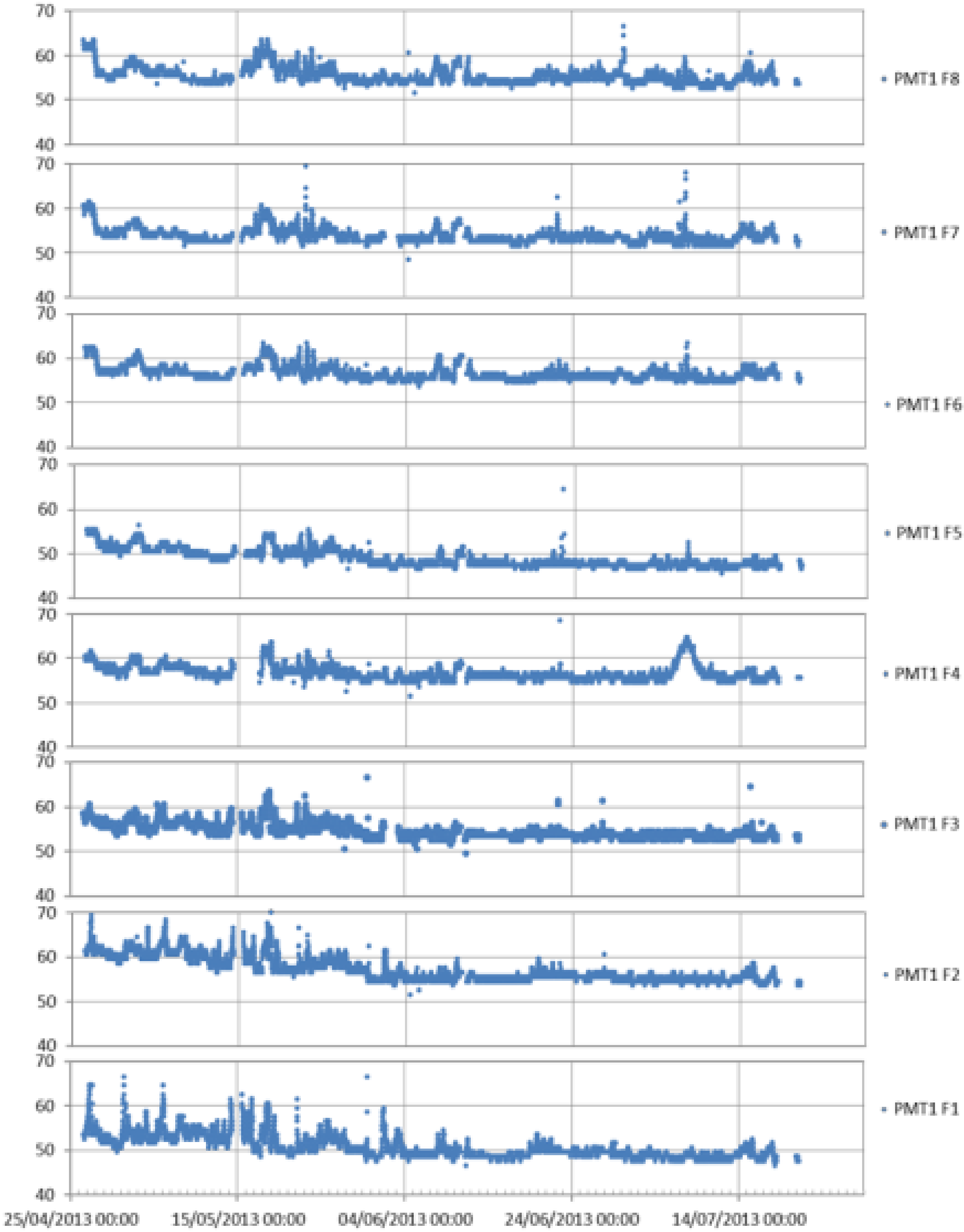

Fig.2.3: average single counting rates in kHz measured in the tower from March to July 2013. Average baselines are within 50-60 kHz. Some period of modest bioluminescence activity are present especially in the first months of monitoring.

2.2 Recent campaigns and planimetry of the site

In 2013 two major sea campaigns took place in the site of Capo Passero. Both of them were carried out by the MTS/FUGRO Chance Company. FUGRO Chance provides a unique range of worldwide activities including geotechnical, survey, subsea and Geoscience services.

The first operation was done in March 22 and 23 and was dedicated to the deployment of the first DU, an 8 floors tower equipped with 4 OMs per storey. The tower was then connected to the CTF described in 1.4, while one Long base line tripod was also installed in the site of Capo Passero.

The DU was first moved to the MTS/FUGRO warehouse located in the harbor of Malta and then transported to the site with the Multi Service Vessel named Nautical Tide equipped with an hydraulic Frame, 30T,10T and 5T Deck Cranes and a heavy work class ROV rated up to 5000 mwd as shown in fig. 2.4

Fig.2.4: the the Multi Service Vessel named Nautical Tide from FUGRO in front of Malta (upper part); the heavy work class ROV rated up to 5000 mwd (lower part).

These were the most important steps of the operation:
March 22, 8.00: The vessel is leaving Malta
March 22, 15.00 : The vessel is in the site
March 22, 16.17: ROV in water and diving
March 22, 18.30: ROV close to the seabed
March 22, 18:35: ROV found the cable , flying along the cable to the CTF.
March 23, 05.42: ROV close to the CTF
March 23, 06.15: start tower descent
March 23, 10.21: touch down of the tower
March 23, 10.33: Start connection and testing procedures
March 23, 11.50: connection of the tower to the CTF, the tower is powered on.
The list was reported to show that the operation was successful and that the tower descent and its connection to the CTF took only less than 6hours.
The second operation took place on July 18-20 and was dedicated to a full survey and a subsea mapping both for the Capo Passer Site and the Catania site. The KM3NET project Phase 1 requires in fact clearing of hazards and other debris from the subsea network location. A visual and a Multibeam survey were also performed for future site planning purposes.
Additionally – outside the KM3NET - recovery of a multidisciplinary Seafloor observatory, Submarine Network 1 and a connection of the LIDO sensor to the previously deployed CFT at Catania Site were performed.
The objectives of this marine operation relevant for KM3NET included
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- Survey and Inspect previously deployed CTF and DU.
- Survey a 1km box NE of Capo Passero CTF and clear area of Hazards.
- Deploy and position Long Base Line Tripod with Beacon.
- Survey Catania South collapsed test tower

Upon arriving at the Capo Passero site, a Multibeam survey was conducted before ROV operations began. After visual contact with the seafloor the ROV commenced a search for the Fishing Aggregating Device (FAD) that was discovered during March operations. Once the FAD was found the ROV followed the line through the water column which lead it to the DU Tower near the seafloor. The line has entangled the Tower from close to the seafloor to just below the buoy modules where the line was cut by the ROV. The ROV then descended to the sea floor and cut the FAD from the weights on bottom. It appeared that the cutting of the FAD line at both the seafloor and buoy modules allowed to the DU Tower to take a more natural position.
When the FAD was cleared of the work area the Fugro ROV searched the Capo Passero site and located the ROV that was lost on a previous INFN project. The heavy lift line was lowered from the vessel with a recovery basket for the ROV and tether to be recovered. Both the ROV and Tether along with a Sonar reflector that was left during operations in March were placed in the recovery basket and recovered to the Nautical Tide.
After the recovery basket was on-board the Nautical Tide a survey grid of lines with 50 meter separation was set up to cover a 1km box NE of the current CTF/DU. The forward looking sonar was used to check the area for any debris. The ROV was positioned in the SW corner of the box and surveyed the first line until it reached the DU at which time it ascended and recorded the heading of the first story. After the heading was noted the ROV returned to the sea floor and continued on the survey line to the NW. The ROV continued surveying the grid until instructed by the INFN representative to stop the survey. During the survey it was noted that what appeared to be a cable was in the survey area. It was seen multiple times but we were unable to reacquire the suspected cable after completion of the survey for further inspection. The only other items of interest noted were random fishing lines in the water column and small debris on the seafloor.

A third Multibeam line was run to capture a 1km area SW of the CTF/DU upon departure from the Capo Passero site.

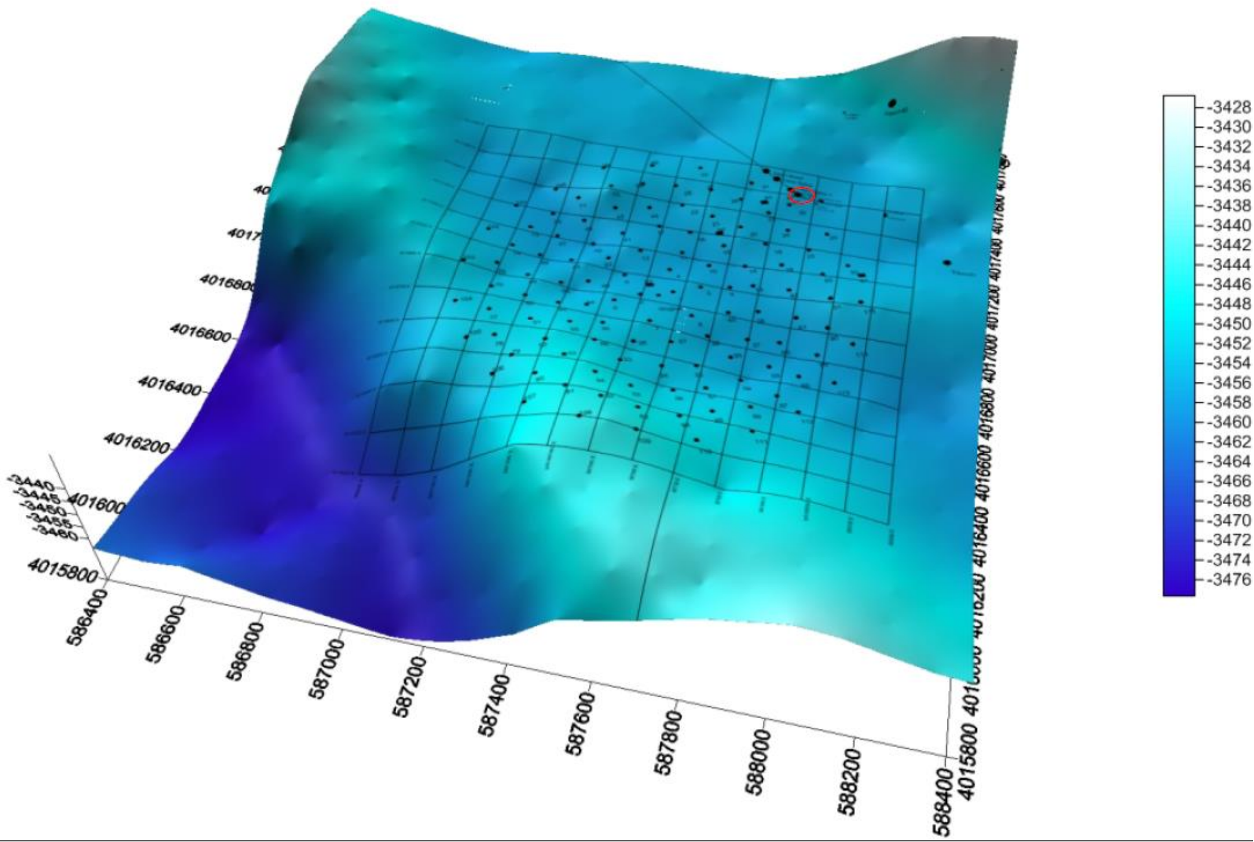

Fig.2.5: the 3D subsea map of the region close to the CTF in Capo Passero. The layout of the telescope is also indicated by the small black dots.

The result of the 1 km x 1 km box survey is reported in the 3D subsea map shown in fig.2.5 where the Z axis has been 'dramatized'. This survey has allowed to determine the flattest region of the sea bed close to the cable termination where to locate the detector. The small black dots correspond to the positions where the future DUs of the telescope will be located, in the large plateau SW off the CTF indicated by the red circle in the plot. Within this area the estimated maximum depth difference is below 30m.

3.The layout of the new infrastructure

The 1kmx 1km subsea mapping of the site of Capo Passero illustrated in fig. 2.5 was done to check the possibility to install a large volume neutrino detector. The optimal layout of this detector was determined on the basis of a full MonteCarlo simulation in order to optimize the detection for the detection of Galactic sources. The simulation includes the neutrino generation, muon propagation, the Cherenkov light production in water, the geometry of each Detection Unit (DU), the hit simulation . The water optical properties and the PMT characteristics are also taken into account together with the 40K optical background. A code that reconstructs the tracks from the hit informations has been also developed.
The same simulation was used to optimize the geometry of a first building block of DUs consisting of 8 towers and 24 strings still compatible to the available electrical power limitation of the infrastructure (8,8 kWatt).
In this chapter, given some details on the simulation, we describe the design of the infrastructure to manage this first block of DUs

3.1 The MC simulation

In order to determine the response of the detector to a high energy neutrino flux a detailed MC simulation was used. In this approach the Cherenkov light produced by the muon tracks in water is detected by photomultiplier tubes (PMTs) contained in glass spheres that are designed to resist the hydrostatic pressure of the deep-sea environment. These instrumented spheres are called Optical Modules (OMs). The geometry of the detector is simulated in a three-dimensional array of OMs attached to vertical structures (Detection Units, DUs). In this sense a sub set of DUs constitutes a detector building block. Several building blocks forms the full detector .
The MC simulation chain for a neutrino telescope can be divided in different steps:

- physics event generation,
- Cherenkov light emission and propagation,
- Addition of environmental background , simulation of the PMT response and reconstruction.

Each step requires dedicated software packages and additional information on the characteristics of the detector, the properties of the medium (water or ice) and the trigger conditions.
Neutrino from sources and backgrounds due to the interaction of cosmic rays with the atmosphere are simulated. High energy muons produced by cosmic-ray interactions with atmospheric nuclei, are simulated using the MUPAGE code which describes the atmospheric muon flux at different water depths. The simultaneous arrival of muons and their energy distribution inside a bundle is also taken into account. Neutrino interactions are simulated with the package GENHEN. All neutrino flavors are considered while the CTEQ6 structure function with NLO corrections are used to simulate the deep inelastic scattering mechanism (DIS).
The neutrino-induced muons are propagated with MUSIC while Cherenkov photon emission inside the active volume of the telescope is treated with the KM3 code . The probability for an OM to be hit is evaluated accounting for water properties, OM geometry and distance from the track. Finally hits due to a constant background are added to simulate K40 decay and bioluminescence.
Then, a reconstruction program, the same used for real data, is applied to the hits to reconstruct tracks after applying some simple trigger algorithms, based essentially on causality.
Using these codes, the detection efficiency for various reconstruction conditions (cuts), the angular resolution and the reconstructed energy can be estimated and the detector configuration optimized accordingly to finally evaluate the performance for the detection of astrophysical neutrino sources.

3.2 The km3 telescope

Thanks to its geographical location in the Northern hemisphere, the KM3 telescope can observe most of the Galactic Plane, including the galactic centre, where the large part of the neutrino candidate sources are located. The KM3 detector design was then optimized for the detection of Galactic sources that are supposed to have a E^{-2} spectrum with a cutoff in the TeV region. In particular the source RXJ1713, whose gamma emission has been extensively measured, is supposed to be one of the best candidate for the emission of high energy neutrinos. A study of the detection efficiency of the KM3NeT neutrino telescope has been made for various detector configurations. The result of the horizontal spacing optimization is shown in figure 3.1 where the number of observation years required for the discovery of the RXJ1713 as a function of the distance between DUs is shown. As deduced from these and similar plots, a detector configuration of around 100-120 DUs each consisting of 15-20 floors, with a distance between DU of about 90-100m provides an effective layout.

Based on these calculations, the configuration of the telescope was determined assuming a 90m distance between DUs, still compliant with the ROV operation requirements. An additional length randomly extracted in the -10m , +10m interval was added to the 90 m distance in order to minimize possible effects induced by the symmetry of the configuration.

The result of the layout for the 115 DUs telescope of Capo Passero is illustrated in fig . 3.2.

The cable from shore, in the upper right part of the picture, is tangent to the footprint. Here the colored dots numbered 1-115 represents the position of the DUs in the sea bed grid which has a spacing of 100m while the green and red DUs connected to the JB1-JB3 correspond to the first part of the detector.

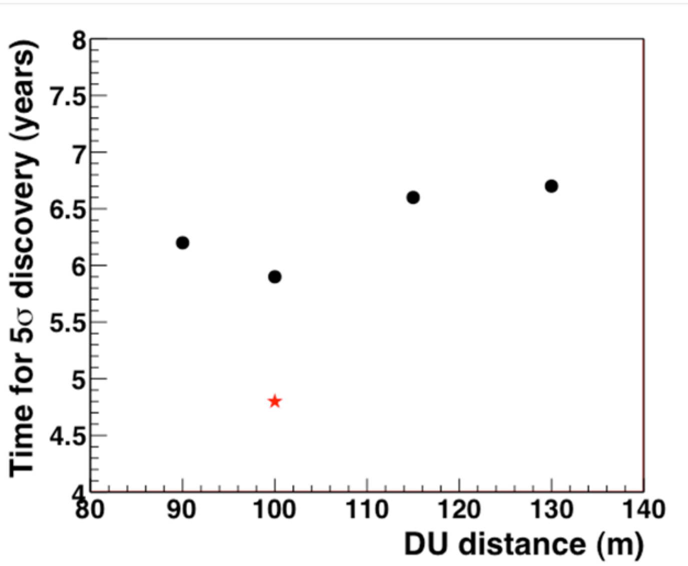

Fig.3.1 Number of years to claim the discovery (5σ 50% probability) of the full KM3NeT detector as a function of string distances for RXJ1713. The red star shows the result for the unbinned search method.

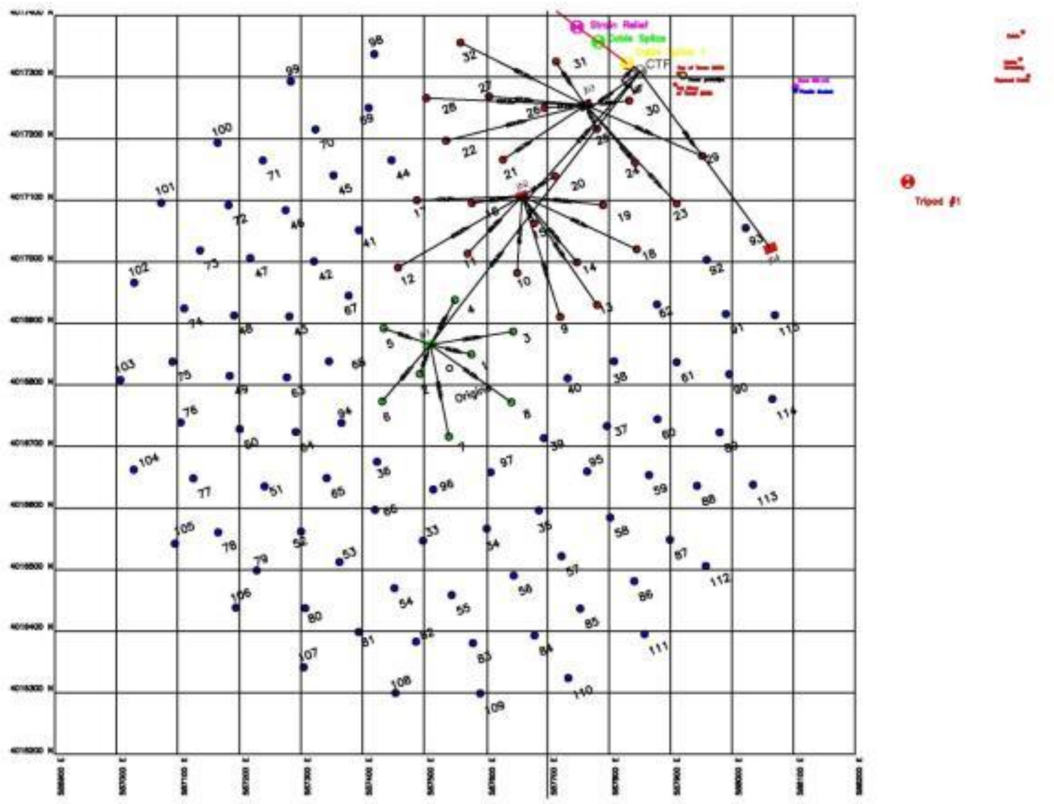

Fig. 3.2: The layout of the 115 DUs for the telescope in Capo Passero

3.3 The layout and the DUs

Due to the electrical power limitation of the infrastructure (8,8 kWatt), only a first building block of DUs consisting of 8 towers and 24 strings illustrated in the previous picture will be installed in the first stage of the project. According to various constraints like the PON(**) funding profile, the status of the design and qualification, the results of the KM3-Fase I TDR , two types of DUs will be connected into the site, namely 8 towers and 24 strings as represented in fig.3.3.

Here the green dots numbered 1-8 and the red dots numbered 9-32 correspond to the position of the 8 towers and 24 strings respectively while the JB1-JB3 correspond to the secondary junction boxes which route the DUs signals to the main cable at the CTF .

The two DU prototypes mainly differ on the design of the mechanical support of the OMs which, in both cases, is anchored to the sea floor and kept upright by a submerged buoy. In the string design, each OM, called Digital Optical Module (DOM), consists of 31 3-inch PMTs [22] housed inside a 17-inch pressure-resistant glass sphere covering almost a 4π field of view while the vertical distance between DOMs is 36m for the neutrino astronomy . The structure of the line comprises two parallel Dyneema ropes (4 mm diameter) of the full height of the line on which the DOMs are attached. Some spacers are added in between the DOMs to maintain the ropes parallel.

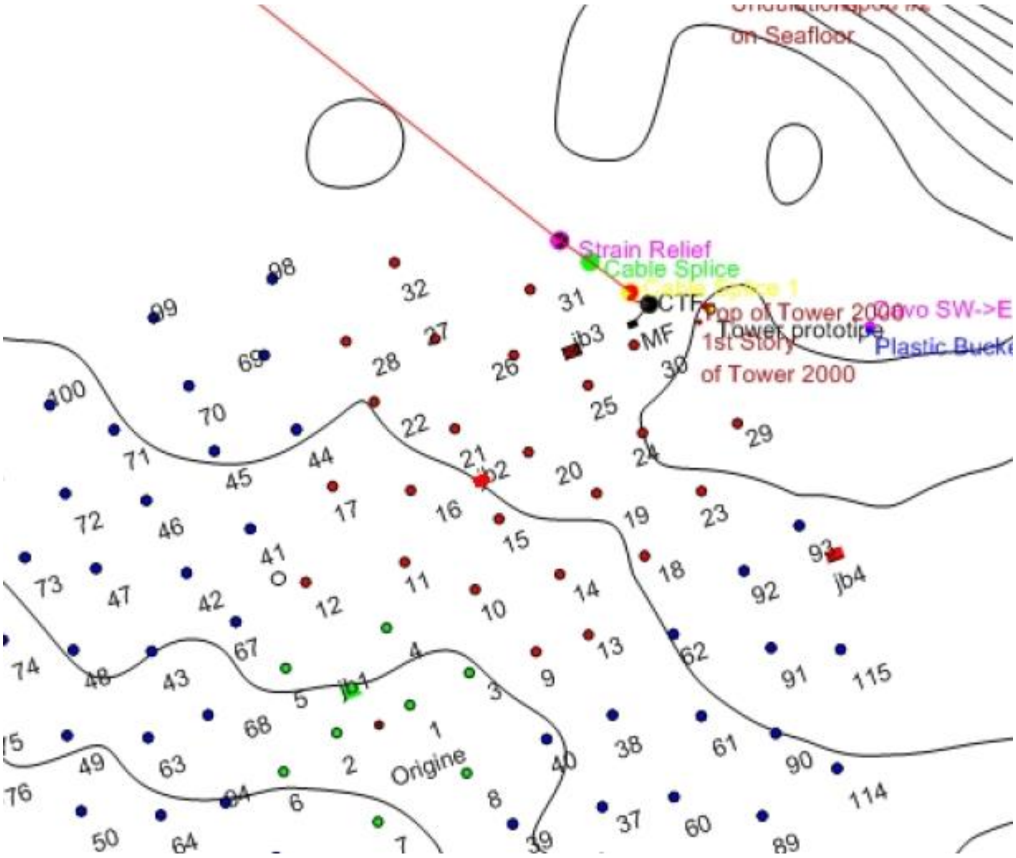

Fig. 3.3: The first building block of DUs in Capo Passero: green and red dots correspond to tower and string respectively.

The data and electric power transmission within the DU is achieved with one Vertical Electro-Optical Cable (VEOC) interconnecting the 18 DOMs and a base container located at the DU foot. The VEOCs will be a Pressure Balanced Oil Filled cable such that the 18 fibres and the 2 copper wires will operate under the ambient hydrostatic pressure. The multiplexing of the signals from the 18 DOM fibres into one fibre is done in the base. Before deployment the full line is wounded on a spherical mechanical structure (LOM) which is then released at the maximum extension of the line as shown in fig 3.4.
For the tower, the mechanical structure is a semi-rigid system composed of a sequence of horizontal elements (storeys) interlinked by a system of tensioning ropes arranged to force each storey to a position perpendicular to its vertical neighbors (see fig. 3.5). In each storey, 6 OMs are located as shown in fig.3.5. Each OM consists of a 13” pressure resistant glass sphere and contains a 10” PMT. Each tower consists 14 floors displaced 20 m apart, and the top buoy. Data and power transmission to each storey is provided by a single SEACON 2 electric conductor, 2 optic fibres cable with two dry connectors at each end. In this configuration, 14 cables of increasing length connect the tower base to the electronic container on each floor.

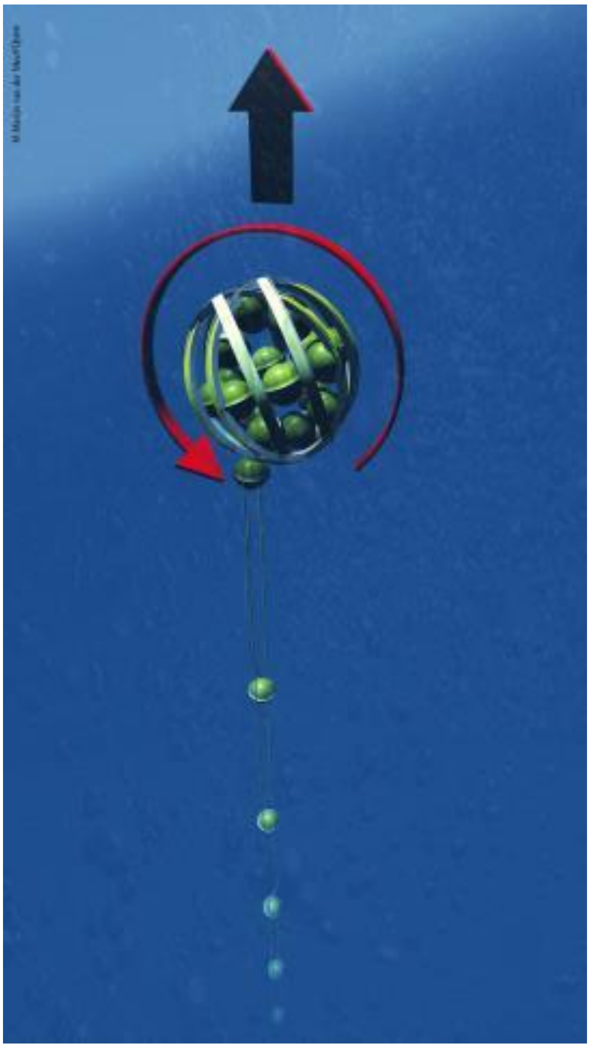

Fig. 3.4: The string concept design.

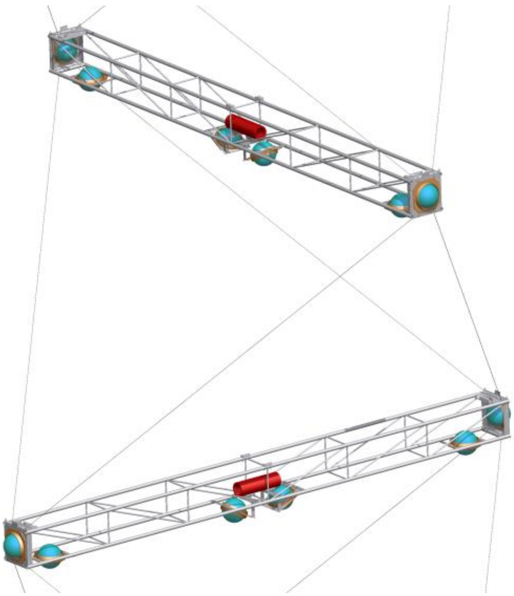

Fig. 3.5: The tower concept design

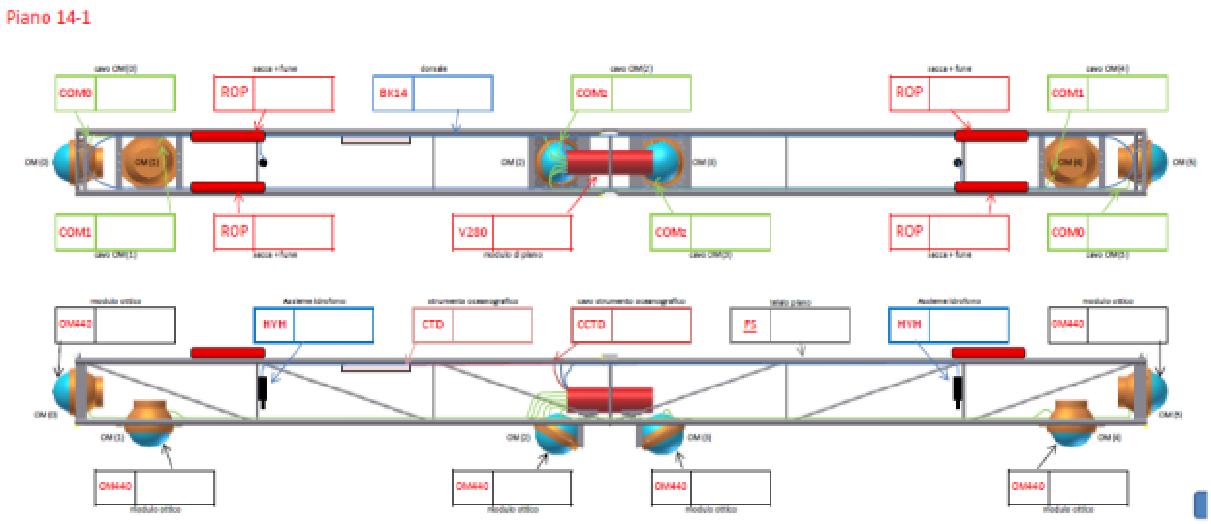

Fig. 3.6: The storey of the tower with the 6 OMs .

3.4 The new Cable Termination Frame

The new cable termination frame will be realized in order to exploit the full capability of power and data transmission of the main electro optical cable, the MVC together with the commercially available underwater mate electro optical connectors.
The CTF itself is not a complicated device but, being a single point failure of the detector, it must designed carefully. The CTF will include an MVC which is a spare copy of the MVC deployed in 2008, presently used to power the 8-floor tower prototype.
Similarly to the present design, the CTF will include a Cable termination Assembling (CTA), a 10 kVolt electrical connector to match the electrical conductor to the MVC input, and 5 ROV mate output connectors each containing 2 electrical wires a 4 optic fibres .
In this configuration the 20 optic fibres of the main cable are unfolded and distributed to the 5 outputs which will be connected via an interlink cable to the 5 Secondary Junction Boxes (SJBs): SJB1 to feed the 8 towers, SJB2 and SJB3 for the 12+12 strings, SJB4 as a spare and SJB5 for the EMSO node.
Concerning the power consumption in the network, an acceptable evaluation gives the following numbers :

- the power provided at the MVC output is: PMVC= 8.5 kWatt @375 V DC
- the power needed by each tower is 0.2 kWatt and assuming 0.2 kWatt consumption in SJB1 a total of Pt=1.8 kWatt is needed to power the 8 towers
- for the EMSO node the 0.2 kWatt in SJB5 must be added to the 0.8 kWatt of the sensors to get a total of 1.0 kWatt
- 0.2+0.2+0.2 = 0.6 kWatt for SJB2-SJB4

Within this estimate, power available for strings is Ps= 8.5 – 1.8 - 1.0 - 0.6 = 5.1 kWatt.
For a 0.2 kWatt consumption on each string, the total number of strings which can be connected to the Capo Passero infrastructure is therefore of the order of 25, well compatible to the 12+12 assumed in this report.

The 5 outputs are underwater wet-mateable connectors supplied by Teledyne-ODI (formerly ODI), the connector model being the NRH (Nautilus Rolling Seal Hybrid) capable of carrying up to 4 fibres and 2 wires..

The specifications for NRH connectors are:

- Insertion loss (IL): <0.5 dB @1310/1550 nm,
- Return loss (RL): <-30 dB #1310/1550 nm,
- Max operational DC voltage: 3,3 kV,
- Max operational current: 30A per circuit.

The tender for the realization of the new CTF is underway. Three companies have been contacted:
ALCATEL, the one who already realized the present three outputs CTF
L3-MARIPRO who realized the NEPTUNE network using the same ALCATEL MVC
SEACON
The MVC which will be mounted in the new CTF , available at LNS, will be sent to L3MARIPRO for testing.

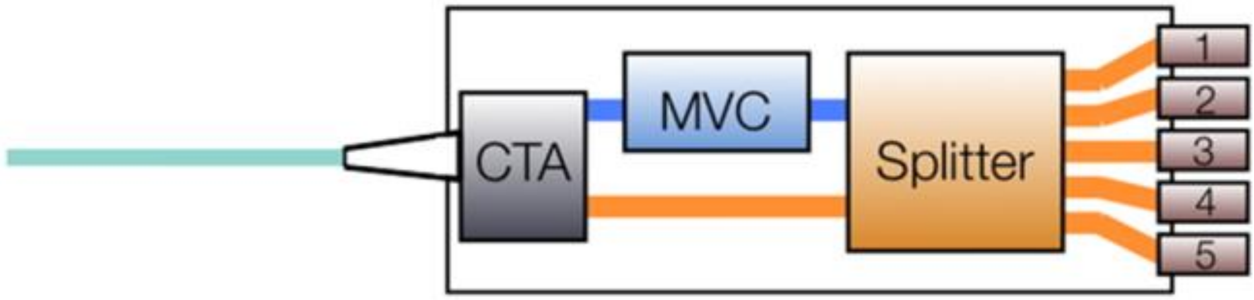

Fig. 3.6 : the New Cable termination Frame

3.5 The Secondary Junction Box

Each secondary junction box serves a group of up to 12 detection units and is located near them so that the distance to the detection units is as short as possible. Its function is to distribute the power coming from the primary junction box to the detection units as well as to manage optical data flux from / to shore. To optimize the assembly and to be as much modular as possible the SJB design includes a frame holding a patch panel for connectors, a manifold for fiber and conductor routing and three pods with different functionality:

- a power pod (JPP)to manage the power supply towards the DUs
- an optic pod(JOP) to manage the optical data flux.
- an electronic pod(EP) for the control and the monitoring of the system

The preliminary design of the structure is reported in fig. 3.7. The support has a cubic shape of 2.5 m x 2.5m x 2.5 m dimensions with the upper part optimized for deployment and the lateral part containing the ROV mate connectors from the CTF (single) and to the DUS (4 connectors per side). The central part of the JB hosts the manifold and the vessels for the optical, power and control systems.

The full cable routing is reported in fig. 3.8. The interlink cable from one of the outputs of the CTF (yellow tag n. 26 in the picture) is connected to the SBJs patch panel JMF and distributed to the three pods through the manifold JMA. The manifold allows an easy assembling and easy testing connection system to drive the power supply and the optical signals to each DU through the three pods. The picture is taken from the documentation system as described in chapter 6.

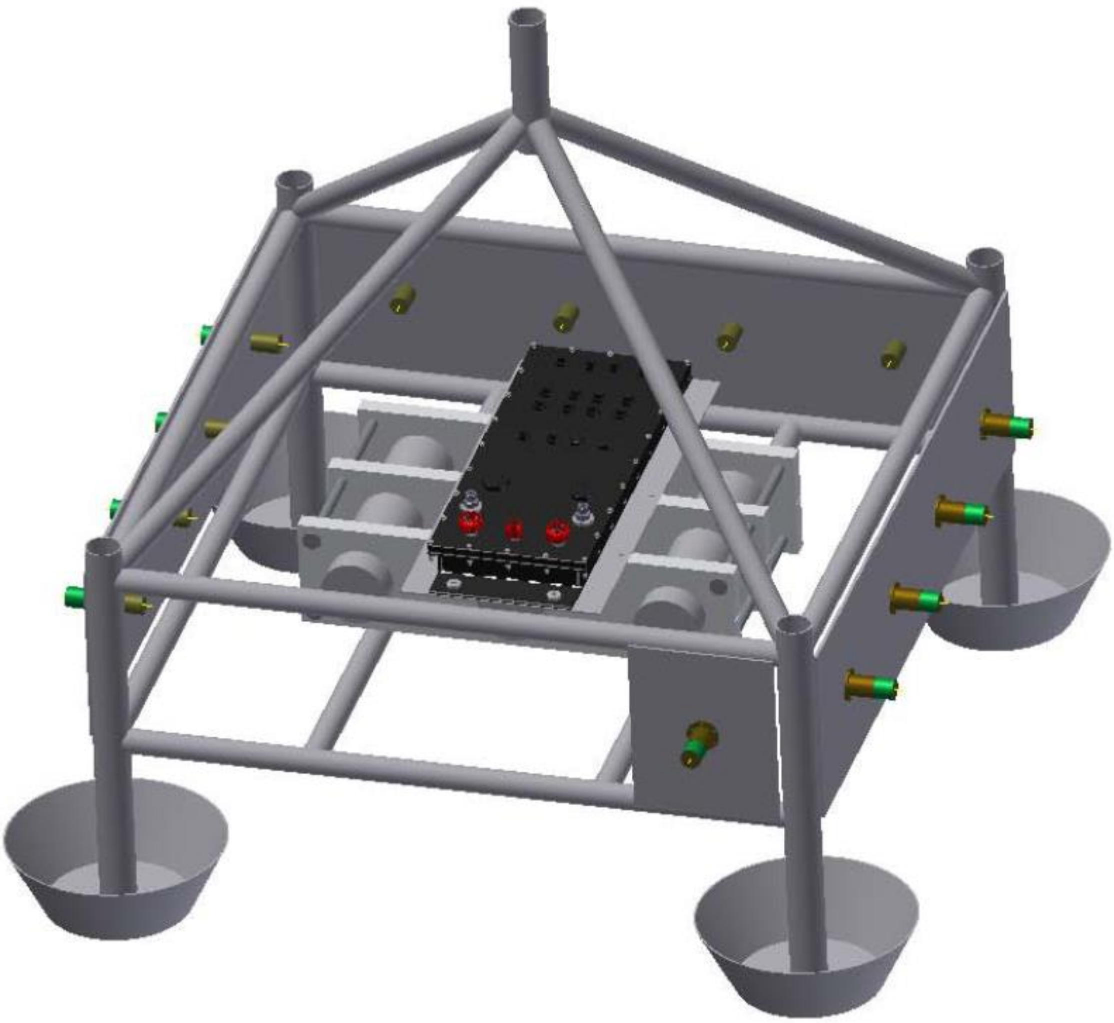

Fig. 3.7: the Secondary Junction Box.

Here different connector types correspond to different colors: optical connector (green) , electrical (red), hybrid dry (brown), hybrid ROVmate (violet) etc. By clicking on each number the full details of the corresponding item are displayed including connector type.
The optic pod JOP hosts the optical amplifiers EDFA, 4 band multiplexers, the power supply board (PSS) and various dry connectors to communicate with the manifold and the remaining vessels.
The electrical pod EP hosts two boards, one for power supply and one with an FPGA for Slow Control and sensor monitoring which is an updated version of the local control board in the floor of the tower, the floor control module (FCM). Finally, the power pod, JPP, in addition to the power supply, contains the Power Control System board (PSS) to manage the switches and the different sensors. More details will be given in the power and optic system description in chap. 4.
The same system is used in the base of the tower DUs. Here the patch panel connects the single floors of the tower similarly to the connection of the DUs in the SBJ while the interlink cable coming from the SBJ has its equivalent on the interlink cable from the CTF, the control electronics remaining the same.

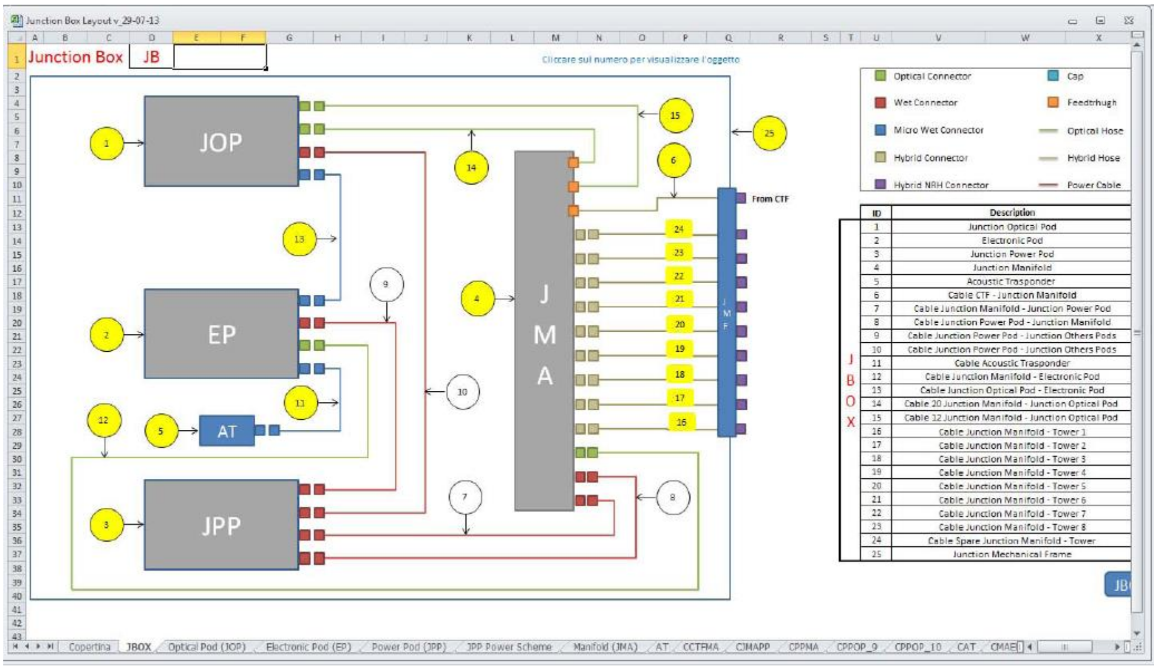

Fig. 3.8: the wiring in the SJB

3.6 The cable network

As shown in fig. 3.2, the sea-bed network consists of the cables from the CFT to each SJB and from the SJB to each detection unit. These cables are called interlink and are equipped with wet mate connectors in order to be connected undersea with an ROV once the SJBs and DUs are in place. The length of each cables is determined according to the position of the DUs with respect to the SJBs while the technical specification are summarized in the following list:

- Electrical conductor: AWG 9
- Fiber type: G 652
- Angle physical contact (APC) in both sides
- Back reflection on optical contacts: < - 45dB
- Cable Colour: Yellow or Orange
- Max outer diameter: < 30 mm
- Buoyancy: Max 250 gr/m
- Cable TAG: Each 10 m

The various lengths are obtained increasing the physical distance by 20% and they have been grouped in 8 'standard' lengths in order to minimize costs according to the following table:

Cable Length (m)	Quantity
310	1
280	4
250	4
200	6
150	6
100	4
90	4
60	3

Each interlink cables will be deployed with a special tray and unfolded by the ROV.
The two terminations of the interlink will be plugged in a couple jumpers installed respectively at the base of the detection unit and at the output of the SJB. The 2 type of jumpers are identical.

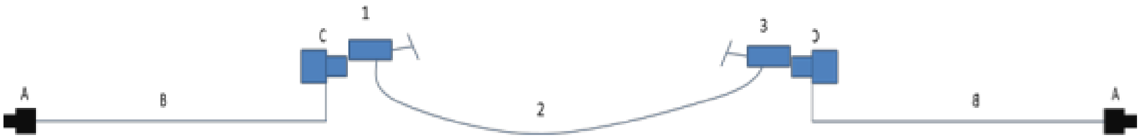

Fig.3.9

As shown on fig. 3.9, each jumper includes a termination A, a SEACON OPTG 4 Pin dry connector (2 optical fibers - 2 electrical wires), a 4m cable B (2 electrical wires (375V - 500W) - 2 optical fibers G652) and a ROV hybrid Bulkhead connector C (2 optical fibers APC, 2 electrical wires). The full connection from the SBJ to each DU base is illustrated in fig. 3.9 .
The optical and electrical simulation of the network is underway. However a preliminary evaluation on the voltage drops and optical losses has been performed.
Assuming the following input values:

- MVC output voltage: 375V
- Available power at MVC output: 8,5 kW
- Power per Tower: 200 W
- Power per line: 220 W
- Power per 8Tower+ 24strings: 7 kW
- Electrical wires: 9AWG
- Distance CFT-SJB1(8 towers): 850m
- Distance CFT-SJB2(12 strings): 550m
- Distance CFT-SJB3(12 strings): 250m

the power losses calculation gives the following values of the SJBs input voltage:

- SJB1: 354.6 V
- SJB2: 353.2 V
- SJB3: 365.0 V

while at the DUs base DU/ Tower input Voltage:

- DU tower(SJB1): 351.2 V
- DU string (SJB2): 349.4 V
- DU string (SJB3): 361.4 V

For the tower the input voltage is still well with specs while for the strings the voltage drop with respect to the 375V is not acceptable: the study for a dedicated solution is underway.
According to this evaluation , the total power consumption in the full network accounts for 400W, around the 5.5% of the total available power.
Concerning the optical losses, a preliminary evaluation was based on the following table where the reported loss and reflection values are well established.

- For dry mate connectors inside pressure vessels it has been adopted the Premium Low Loss SM UPC and APC Connector type exceeding IEC 61753-1 standard for Random Mating Grade B, which shows the following performance: Mean Loss ≤ 0.07 dB
- Max Loss ≤ 0.15dB (97% of the connector population)

This choice enables to achieve an easy assembly test without incurring into high losses. It is important to say that the Premium Low Loss SM UPC connector has been extensively used in the 8-floors tower connected to the site: the optical path includes more than 10 of these connections (for the floors on the top) and it works according to the reported specs.

Connection Type	Max loss dB	Quantity	Total loss per type dB	Reflection dB	Ref. Standard
ROV mateable (SJB external + 1 interlink)	0.5	3	1.5	45	N/A
Dry mateable (SJB internal)	0.3	3	0.9	45	N/A
Dry mateable (inside pressure vessels, only for tower SJB1)	0.15	5	0.75	45	IEC 61753-1 (*)
	Total connector losses		3.15		

4. Optical and power systems

The layout of the sea bed network in Capo Passero has already been described in the previous chapter. Here we'll give some details in the optical and power system which is realized in order to be fully compliant to the two DU designs, towers and strings. The design complies to the tree structure of the detector. In particular, the different storeys connected at the base of each DUs is in correspondence to the different DUs connected to each SJBs. To this extent the three pods structure of the SJB will be the same at the DU base.

4.1The photonic system for KM3NeT-IT Seafloor

This section will focus on the description of the optical path extending from the output port of the CTF to the DU base.

The optical path and the main components of the submarine network from the CTF to the Secondary Junction Box SJB1 is reported in fig.4.1 for the 8 towers while for the string installation the schematic will be very similar. In particular the external optical interfaces and optical routing/distribution is to be considered already defined and ready for tender and procurement while we expect the SJB2 and SBJ3 optical internal assembly to be completely defined accordingly to the string requirements.

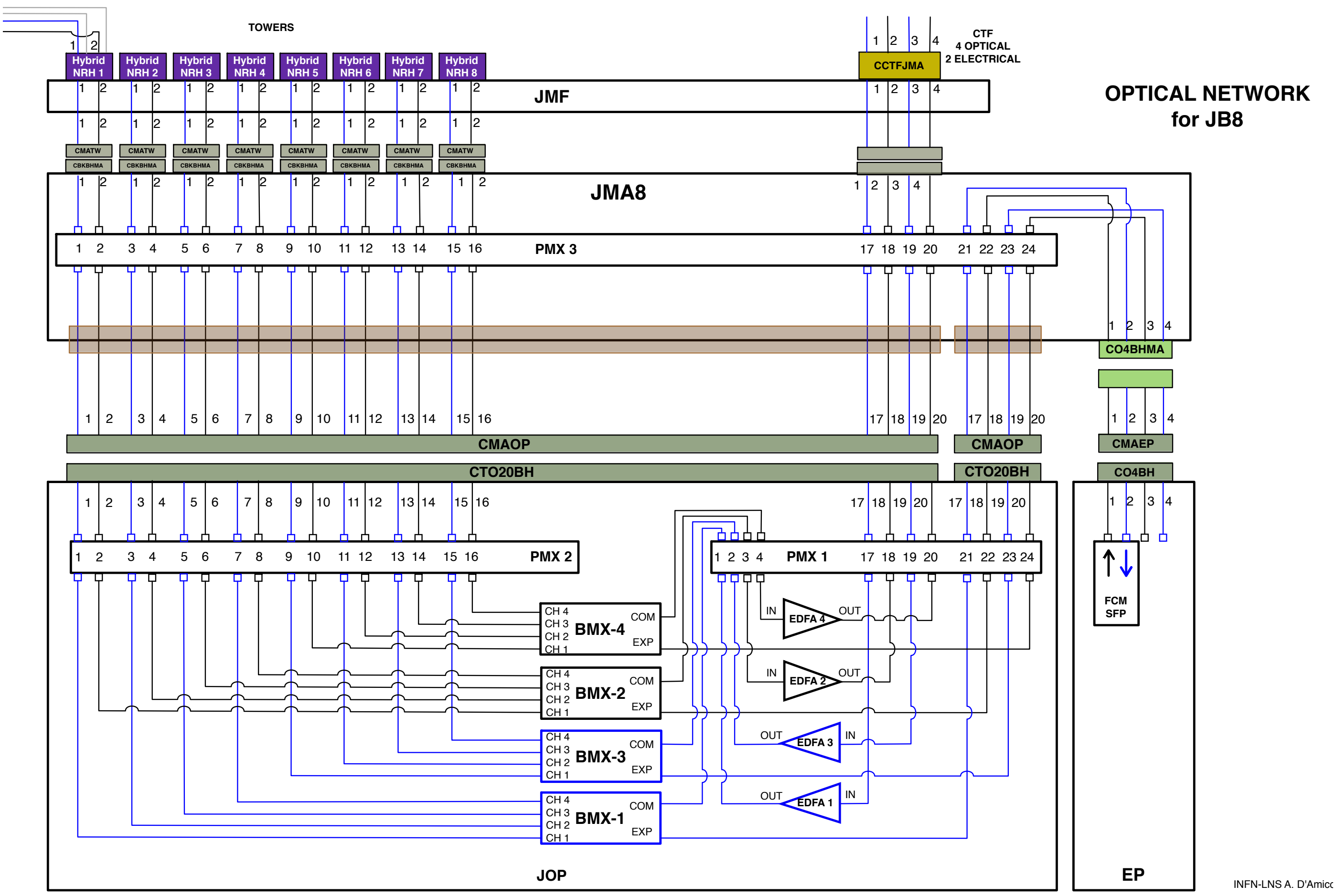

Fig.4.1: the optical network for the towers.

In fig.4.1 the blue and black colors of the fibres correspond to downstream or upstream signals respectively. Here the 4 optic fibres from the CTF enter the optic pod JOP in the SJB1 through the panel JMF and the manifold JMA8.
This manifold is just a passive optical routing to distribute the 4 fibres of the interlink cable from the CTF to the optical and electrical pods and finally to the DUs connected to the SJB.
In the same figure the specification of the main optical connectors are also indicated , the pink color indicating a feed through in the manifold:

- The ROV mate plug in front panel of the SJB
- 2 SEACON OP-T-20 optical 20 fiber connector in the optic pod
- 8 (for tower)/12 (for strings) optical 4 fiber connector in the manifold
- 8 (for tower)/12 (for strings) jumpers as described in 3.6

The optic pod hosts some passive DWDM optical filters. Their function is to mix (multiplex/demultiplex) different groups of DWDM channels into one optical fibre. The passive optics in the optic pod is thus made by 4 optical band filters modules BMX (Band Multiplexer) as shown in figure 4.2.
Each tower receives 15 DWDM channels and transmits back to shore 15 DWDM channels, received and transmitted channels have the same frequencies. Each filter handles up to 15 DWDM channels equally spaced at 50 GHz (on the ITU standard frequency grid).

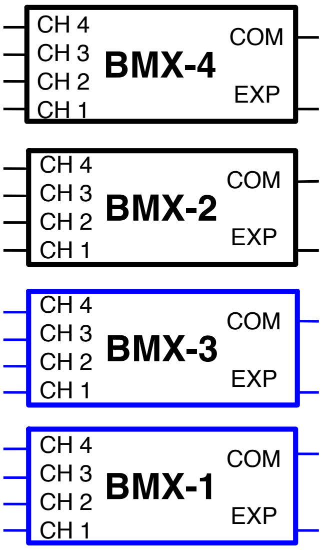

Figure 4.2. Set of 4 DWDM band filters

Two set of band filters are used for the downstream transmission (shore-station to tower) while the remaining two are used for the upstream data. The passive optics in the Junction Box is thus capable to handle up to 62 DWDM channels per fibre.
Each group of 4 band filters will be assembled together in a single bandpass module with aluminium package and mounted on the mechanical support of the optic pod . Each module will have 6 fibre pigtails of 0.5/1 m (TBC) length and fibre type will be 900μm tight buffer terminated with LC/UPC connectors.
The specifications for the bandpass module filters are reported in fig. 4.3
The optic pod is also hosting 4 optical Erbium Doped Fibre Amplifiers (EDFA), one module shown in fig. 4.4. Two modules are configured as preamplifiers and the remaining two as booster .
The optical Gain introduced by the EDFA stages is typically:

- For the Boosters: 18 dB
- For the Preamplifiers: 13 dB

The EDFA stages offshore operate together with the EDFA stages at the shore station, which will introduce further gain into the system budget:

- Shore station Boosters: 10 dB
- Preamplifiers: 15 dB

It is foreseen that with these gain settings and with a transceiver modules sensitivity of -24 dB (worst case) the total system margin is 8 dB

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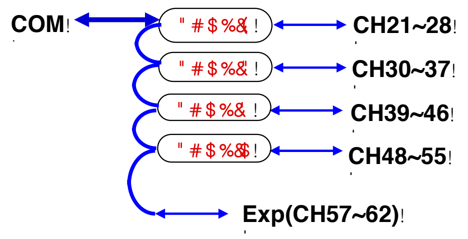
PN: BWDM-A-100-CH21-04-1-900T-52 — **Date: 2013.02.22 Rev 1.0**

A Configuration



B	**Channel Optical Performance**					**Spec**
0	**Parameter**	**Region**	**Measure from => to**	**Unit**		
1	Optical Operating Wavelength			nm		1520~1580
2	Channels					4
3	Center wavelength			nm		See configuration
4	Insertion Loss		COM<=> Channels	Max	dB	2.00
			COM<=> Exp	Max	dB	1.50
5	Isolation	adjacent channel		Min	dB	20
		Exp				12
6	Ripple	passband	COM=>Channels	Max	dB	0.5
a	*Insertion Loss include connector Loss(A pair of connector loss<0.25dB.)*					
C	**General Optical Performance**					**Spec**
1	Directivity			Min	dB	45
2	Return Loss			Min	dB	45
3	Polarization Dependant Loss			Max	dB	0.2
4	Polarization Mode Dispersion			Max	dB	0.15(DG)
5	Power Handling			Max	mW	300
D	**Temperature Ranges**					**Spec**
1	Operating Temp			°C		0 to 70
2	Storage Temp			°C		-40 to 85
E	**Mechanical and Package**					**Spec**
1	Fiber Length			m		1±0.1
2	Box Dimensions (L x W x H)			mm		AL box, See apperance drawing
3	Fiber Type					900um Tight Buffer
4	Connector Type					LC/UPC
F	**Miscellaneous**					**Spec**
1	DG = Design Guaranteed					
2	All specifications include the effect of operating temperature and all states of polarization.					

Figure 4.3. BMX module specifications

Fig.4.4: The EDFA module.

Parameters	Unit	Min	Typ	Max	Notes
Minimum Wavelength range in vacuum (C-Band)	nm	1530		1562	
Input Power with gain flattening	dBm	-22		+13	
Output SIGNAL power range	dBm	-10		20	Includes VOA
Nominal Gain	dB		18		VOA=Minimum (1dB)
VOA Attenuation setting	dB	1		15	For VOA > 1dB, the net gain of the amplifier is decreased
VOA Repeatability	dB			0.1	
Noise Figure	dB			6.5	At G=18dB (Minimum VOA of 1dB). For G<18, NF<6.5 + (18-G)
Gain Flatness over entire gain bandwidth (Pk-Pk)	dB		1.5	2	
Steady State Gain, Power Stability	%			±5	
Maximum ASE backward power out of input port	dBm			-20	
Residual Pump Power out of Input port	dBm			-30	
Residual Pump Power out of Output port	dBm			-20	
Optical Return Loss (any port, pump off)	dB	40			
Polarization Dependence Gain	dB		0.35	0.5	
Polarization Mode Dispersion	ps			0.5	
Multipath Interference	dB			-40	

Fig. 4.5: The EDFA module optical specifications.

Parameter	Units	Specification			Notes
		Min.	Typ	Max.	
Supply voltage Stead state current	V A	4.75	5.0	5.25 1.8	
Startup current	A			3	First seconds after cold boot
In-rush current	A			4.5	
Steady state power consumption	W			9.5	Overall operating conditions and at EOL

Fig. 4.6: The EDFA module electrical specifications

All the internal interconnections fulfil the following specifications:
Patch Panels (PMX) are used to interconnect all the optical pigtails the passive in the optic pod and the Junction Box Manifold Assembly (JMA).

- The optical pigtails in the optic pod are terminated on LC/UPC (grade A) connectors to ease the interfacing with optical devices.
- The optical pigtails in the JMA are terminated with LC/APC (grade A) connectors to have a better suppression of back scattered light.
- Fibre type is G.652D (low loss fibre single mode standard fibre) for all the cabling.
- Fibre type is SMF28 (G.652 type) for all the devices in the network.
- Fibres are coated with 900μm tight buffer.

The optic pod is also connected to the electrical pod where the local slow control system is hosted. This connection is made available through one of the 2 SEACON OP-T-20 optical 20 fiber connectors. The item connecting the two pods will be a 2m length (TBC) jumper. The terminal connectors on this jumper have the same optical characteristics:

- Insertion Loss (IL): <0.3 dB @ 1310/1550 nm
- Return Loss (RL): <-40 dB @ 1310/1550 nm

The maximum total insertion loss permitted for the “photonics–electronics jumper” is 0.6 dB.
The optical signal conveyed by this connection is extracted and inserted by the bandpass modules in the optic pod .
The electro-optical system for the infrastructure slow control is based on the FCM (floor control module) board and hosts SFP transceivers with frequency spacing of 50 GHz.
The DWDM frequency of the slow control channels is assigned out of the bandpass module pass band and share the same fibres used for readout data transmission. Frequencies of the slow control can be in the range ch.57 to ch.62 (ITU channel numbering). Ch. 57 will be used for the Junction Box slow control channel.
The optical path for the strings is reported in fig. 4.7.
Here the 4 optic fibres of the interlink cable from the CTF enter the the optic pod of the SJB through one of the 2 SEACON OP-T-20 optical 20 fiber connectors of the JOP. One out of the 4 fibers (the green one) is used in both directions by the time calibration, detector control and slow control systems of the detector. The splitters 1:4 and 1:16 (in orange) distribute the SC signal to all the DUs and then to each single DOM. The same green fibre drives the control system of the SJB with two dedicate wave lengths similarly to what happens with the tower DUs.
The remaining 3 fibres (in blue) are used by the Data Acquisition. The components indicated “50-200 GHz” represents optical interleavers to concentrate the signals from 4 DUs to shore in one single fibre.

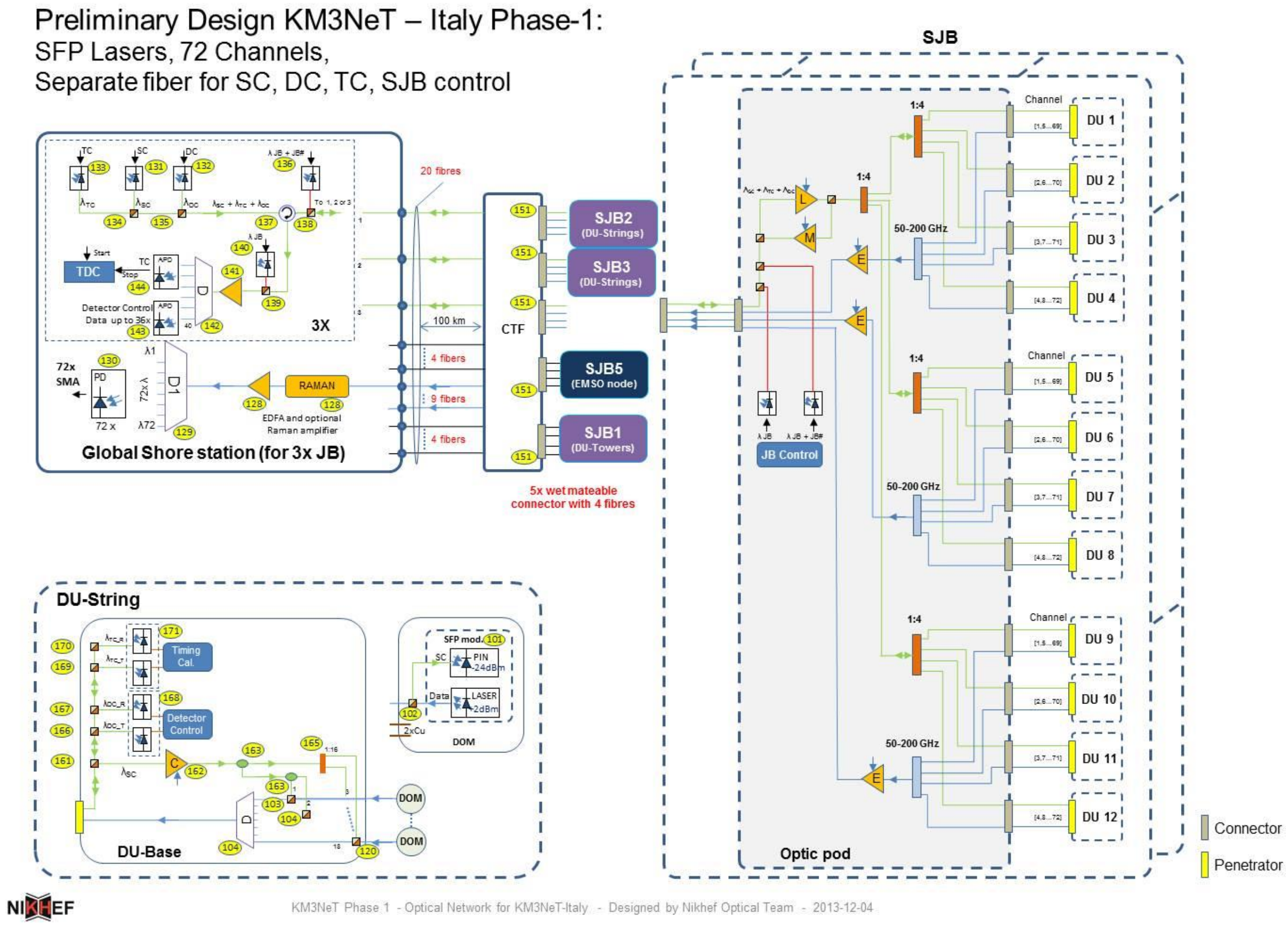


Fig.4.7: the optical path for the strings

4.2 The power system for KM3NeT-IT Seafloor

Part of the power system of the sea network is located inside the power pod hosted in the Junction box, as illustrated in fig. 4.8, in particular the Power pod hosts the portion of power system able to distribute the power coming from the MVC to the users.

The users are: 8 towers/12 strings, a beacon and all the local electrical loads located in the SJB electrical pod EP and optic pod JOP.

All the distribution lines are remotely switchable except for the local line that feeds the control system. The communication between the local control system and shore is realized through a FCM board (located in the EP) via optical fibres.

The JOP contains the Power Supply System (PSS) board and the Power Control System (PCS) board. The PSS allows voltage conversion from 375 V, delivered by the MVC, to low voltages required by all the electrical loads.

The PCS allows monitoring and control of the electrical parameters of all the distribution lines, temperature and humidity measurement and remote switch actuation.
Both the electrical and the optic pods contain a PSS board fed via a switched line (Figure 4.8).
In the event of water ingress in the EP or in case of communication loss between the PCS and the FCM boards located inside the EP, the PSB guarantees the output lines feeding, thanks to a time-out system that automatically actuate all the switches of these lines.
PCS and FCM boards communicate via an isolated serial RS232, the FCM guarantee the communication with the shore station via optical fibres.

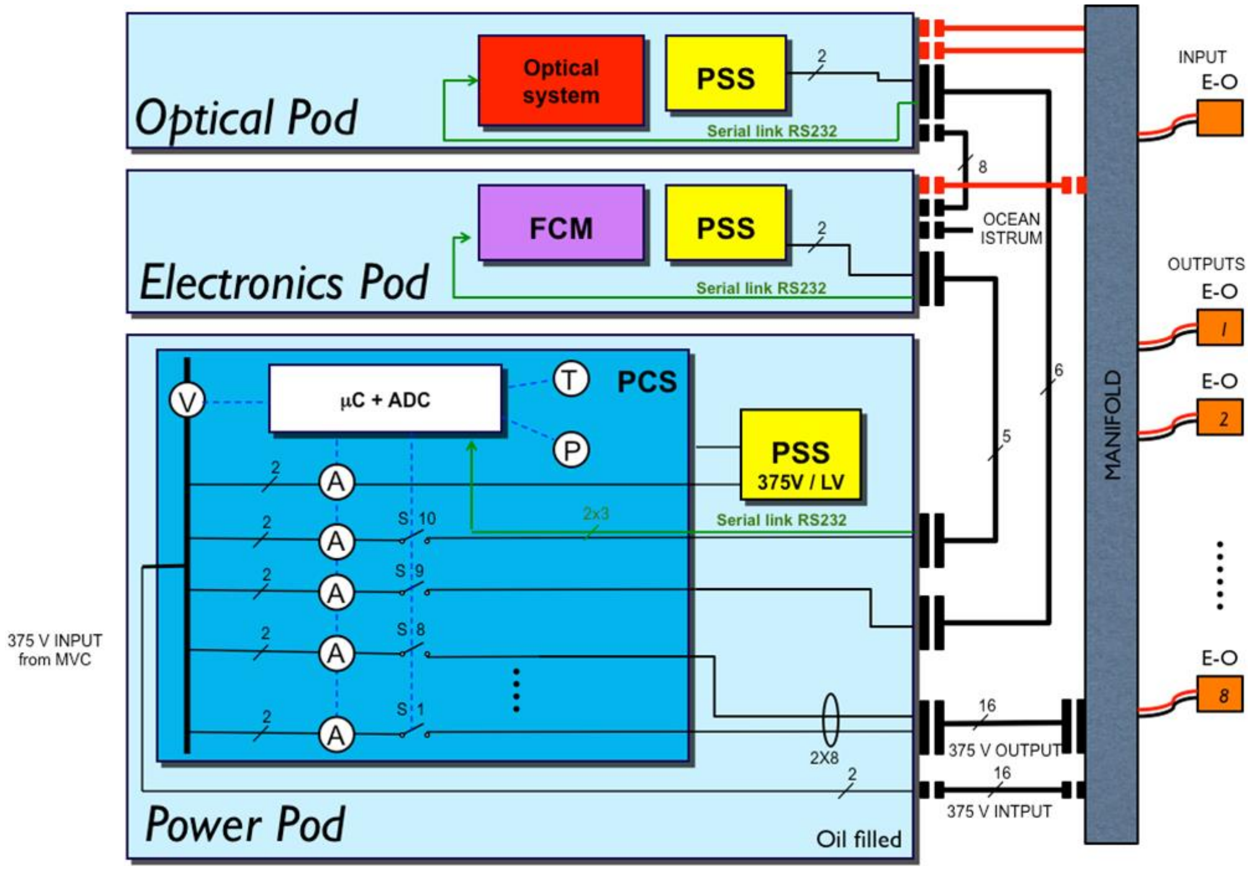


Fig.4.8 : schematic of the power system in the SJB

4.2.1 The power supply system board (PSS)

The Power supply Board (Figure 4.8) converts the 375V to a series of low voltages required by the users, its main features are listed below:

- Max working pressure 400 Bar,
- Working environment: oil bath,
- Protection against input transient overvoltage,
- Soft start outputs (3.3V, 1.8V, 1.2V),
- Flexible start up output sequencing,
- Current and voltage monitoring,
- 50 W maximum total outputs (included DC/DC conversion losses),
- Low output voltage ripple,
- Isolate power supply for oceanographic instrumentation.

In Figure 4.9 the picture of the PSS first release is shownç

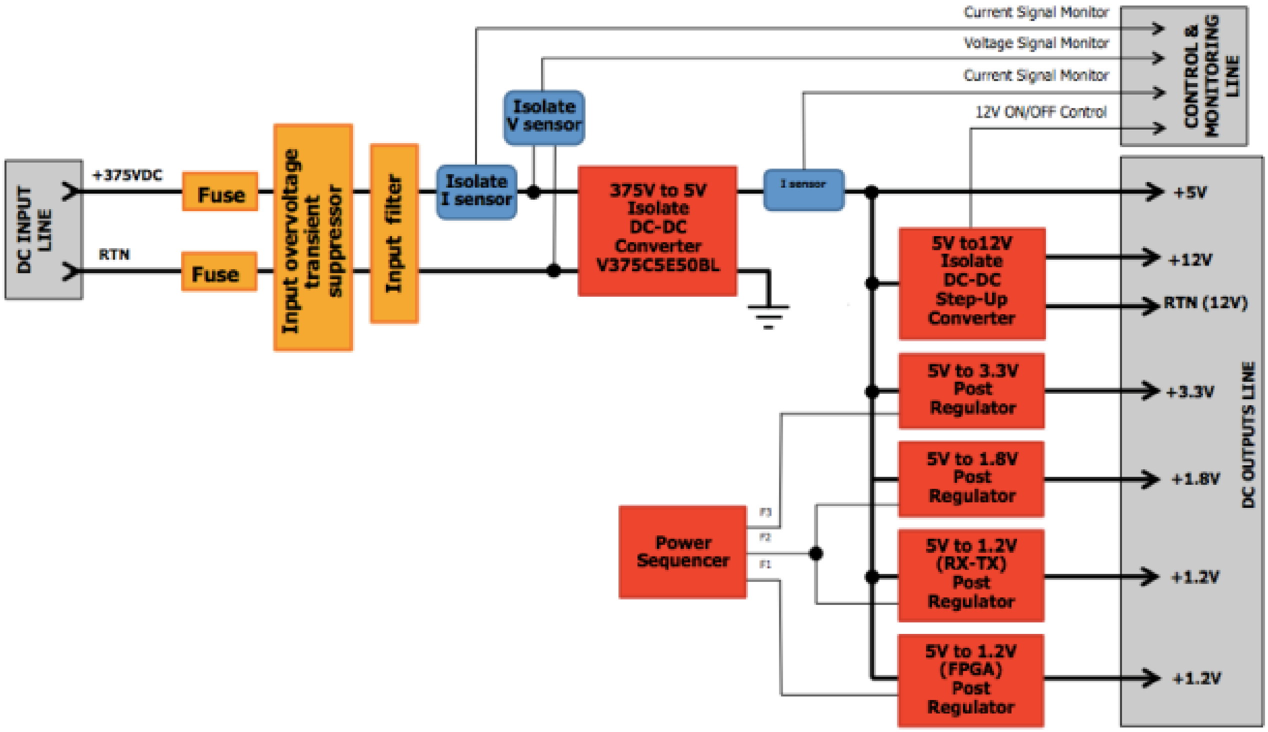


Fig.4.8: The power supply board

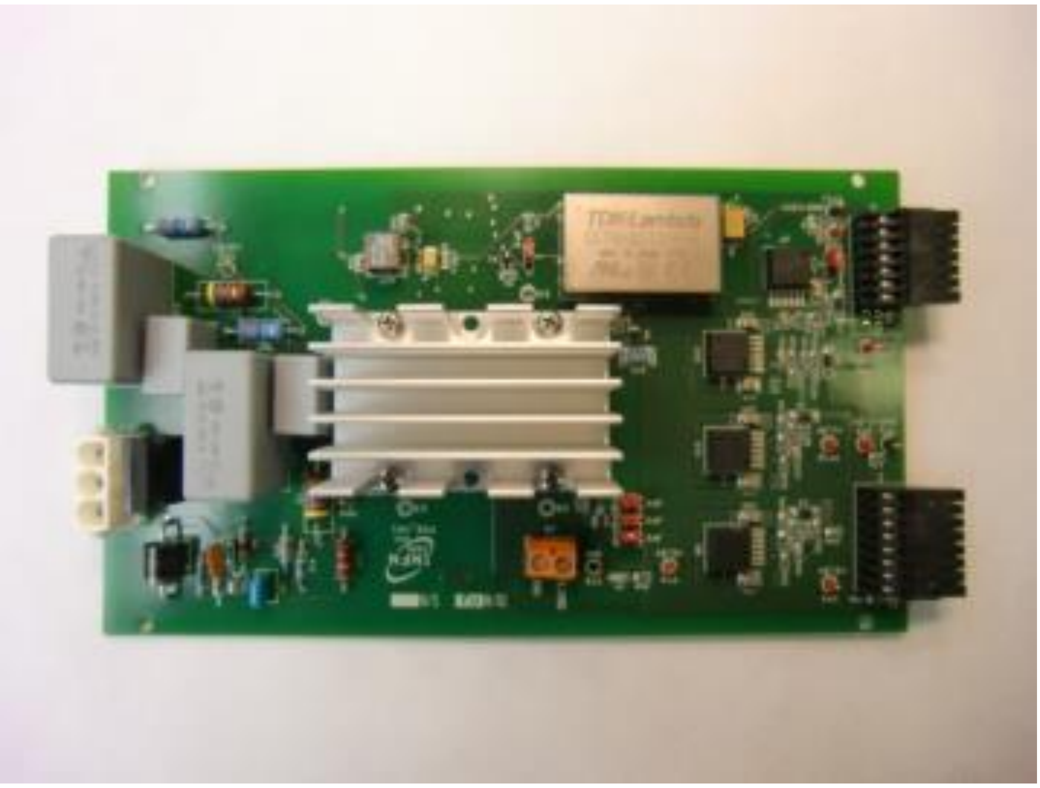


Fig. 4.9: First release of the power system board

4.2.2 The power control system board (PCS)

The Power Control Board (Figure 4.10) is dedicated to the monitoring and control of the distribution lines and pods ambient parameters; its main features are the following:

- Max working pressure 400 Bar,
- Working environment: oil bath,
- Working voltage 375V DC, max power 5 kW,
- Monitoring of all the input and outputs lines electrical parameters (V, I),
- Monitoring of ambient parameters: temperature, pressure, water ingress (in the 3 pods),
- Remotely operated switches in all the output lines with a soft start system (controlled voltage ramp),
- Communication interface between PSS and FCM via isolated asynchronous serial RS232,
- Output short circuit protection. In case of an output line fuse blow up the 375 V return will be opened to completely isolate the output load affected by the fault,
- Time-out system that automatically actuate all the switches of the output lines in case of communication loss between PSS and FCM.
- Autonomous switch off for over current threshold.

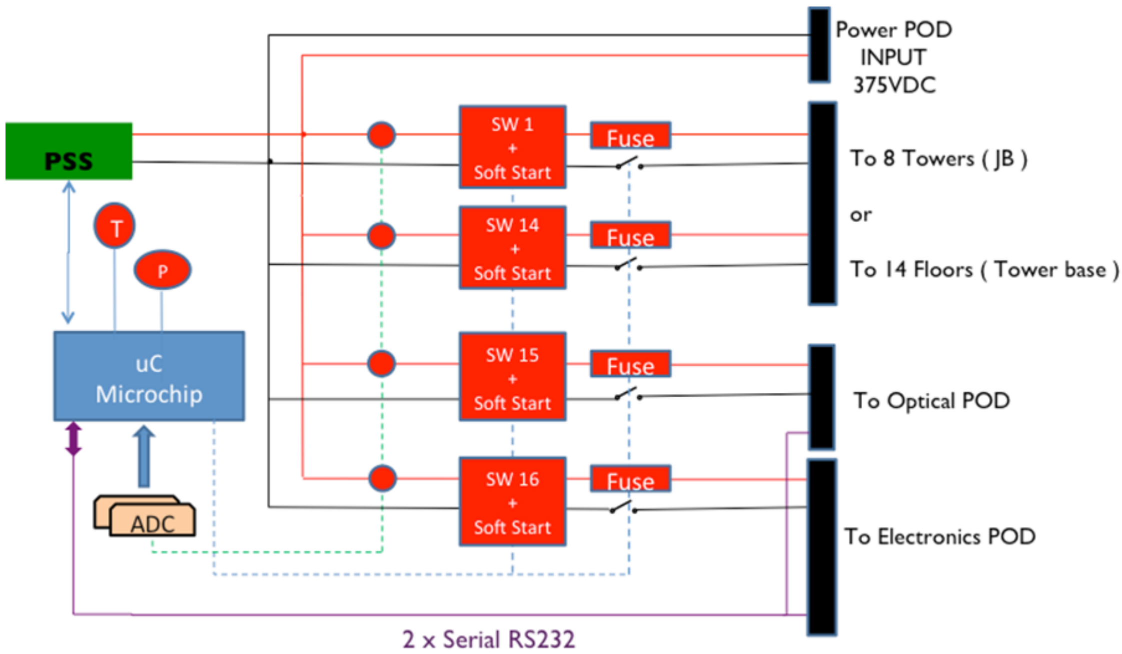


Fig.4.10: The power control board

5. SEA OPERATIONS

The deployment of the sea bed network and the first block of DU will be assigned to a private Company by a public tender. The tender will be done to provide the logistic, support and installation of:

- Up to 8 Detection Units type 'tower'
- Up to 24 Detection Units type 'string'
- Up to 4 Junction Boxes and cabling
- 1 Manifold and cabling
- Maintenance of a cable termination frame (CTF)
- Maintenance and connection of all the above units to a seafloor and
- communication network.
- Deployment and connection of one test 'string'

The activity will start 2014 with the deployment of the test string and continue with the seafloor network, followed by the installation of 8 towers and 24 strings. Preferred operational period in the Ionian Sea is between March and October.
All in all 11 Marine operations are planned with an overall 50 days offshore operation. This includes contingency for e.g. bad weather planning.
To execute this work both off shore and on shore support operations are required:

Offshore Marine Operations

- Management:
  - Project Management, QA and procedure development
  - HSE Planning and Management
  - Subsea engineering support
  - Pre+operations support services
  - Post+operations reporting

- Vessel:
  - DP2 positioning system
  - Minimum 10 t deck crane to move equipment on deck
  - Preferable a more powerful second crane (25t) for loading activities
  - A+frame crane to launch equipment
  - Minimum 200 sqm clear deck space
  - State of the art rescue and safety system on board
  - Proven safety record
  - Operations Room for INFN representatives
  - Quarters for INFN representatives

- ROV:
  - Integrated work class ROV rated to minimum 4000msw
  - Sophisticated LARS (e.g moon+pool) to improve working range
  - 2 Manipulators (7 Function)
  - Fully equipped light and camera systems (preferable HD)
  - Sophisticated integrated positioning system
  - ROV crew with ultra deep deep sea operations experience (+3000 m
  - water depth) and demonstrable skills in various deep sea operations (CV)

Onshore Marine Operations

- Logistics:
  - Pick+up/Mobilization of equipment INFN Laboratory to vessel
  - Handling of agency and port fees

- Support of customs clearance and export procedure (project is in international waters)
- Where necessary inland transport of INFN crew

- Additional Services:
  - Covered workshop area for temporary storage, equipment testing and job preparation. Min 400 sqm Direct access of workshop to quay area to minimize transportation after testing and mobilisation
  - Possibility to rent additional manpower
  - Forklift and crane equipment available (min 30 t crane and 15 t forklift)
  - Pest controlled area

For the full operation we assume the following:

- 4 Marine Operations for Tower deployment 2 towers per operation: 12 days
- 4 Marine Operations for String deployment 3+3 strings per operation: 16 days
- 1 Marine operation for JB MF deployment: 4 days
- 1 Marine operation for CTF change: 4 days
- Deployment test string: 3 days

Contingency 30%: 11 days
Grand total of: 50 days
corresponding to an estimated 2.5 MEuro cost for the complete operation.

	Marker bouys	8 off		
@JB1	2008		8 to JB1	7
		Interlink 2008		
	2007		7 to JB1	8
		Interlink 2007		
	2002		2 to JB1	6
		Interlink 2002		
	2006		6 to JB1	2
		Interlink 2006		
	2001		1 to JB1	3
		Interlink 2001		
	2003		3 to JB1	1
		Interlink 2003		
	2004		4 to JB1	4
		Interlink 2004		
	2005		5 to JB1	5
		Interlink 2005		

	Marker bouys	24 off		
@JB2	1009		9 to JB2	9
		Interlink 1009		
	1013		13 to JB2	13
		Interlink 1013		
	1018		18 to JB2	18
		Interlik 1018		

Fig.5.1 Part of the installation sequence: each color corresponds to one operation

6. The shore station

According to the "all data to shore" approach, the shore station is where all the data produced by the submarine infrastructure are collected and elaborated. Moreover it is the control center where the off-shore detector is operated and monitored. The Portopalo shore station is organized according to the following structure:

- Computing resources for the online Trigger and Data Acquisition System (TriDAS) and the Slow Control System (SCS).
- Computing resources for monitoring and control.
- Local storage and data base interface
- Network infrastructures
- Power Suppliy infrastructure

The shore station infrastructure is designed to host the control and DAQ resources for both the 8 KM3NeT-Ita Tower Units and the Phase1 and Phase2 KM3NeT Detection Units.

6.1 Infrastructure for KM3NeT Phase 1

The general design for the DAQ of the KM3NeT Phase 1 detector is sketched in Figure 6.6. In the present case, the stage of timeslice framing is performed off-shore at any single CLBs. The first layer of both optical and acoustic TriDAS is represented by the *DataQueue* (DQ) servers. DQs steer the different kind of data-streams (optical, acoustic and from the instruments onboard of the CLBs such as tilt-meter and compass) to the corresponding processing units, which for the optical and acoustic data are called *DataFilters* (DF). Similarly to the TCPU the 8 Towers TriDAS, one At the occurrence of a trigger seed in some timeslice, the DF w process cuts out an excerpt of data from the continuous stream few microseconds around the seed and send it to the *Event Writer* (EW). The EW writes the selected data to a file on the local temporary storage device.

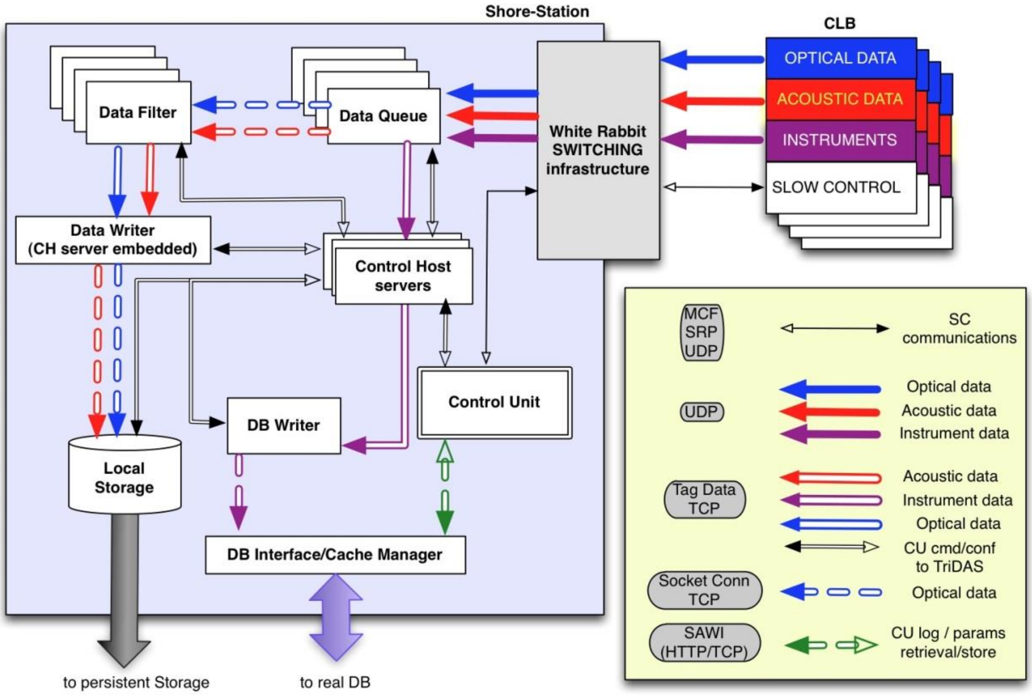


Figure 6.6. Global DAQ design for the KM3NeT Phase 1 and Phase 2 detector.

The Front End to the off-shore detector is represented by the multy-level White Rabbit switching infrastructure, as sketched in Figure 6.7 for the case of the Phase 1 detector. The switches at Level 1 are responsible to disentangle the incoming physics/instruments data from the pure White Rabbit data-stream for synchronization. The current technology used to implement the Level 1 switches is mainly based on 1 GbE connections. Each switch has 18 ports 1 GbE (whose one is used for uplink). Each Level 1 switch is sized 1 U rack mountable.

Willing to grant a maximum allowed bandwidth per DOM of 200 Mbps (in order to deal with long lasting exceptionally intense burst of bioluminescence), only 5 CLBs must be connected by each Level 1 switch. This implies for Phase 1 detector a total number of about 110 switches, which can be arranged into 3 standard racks. It is worthy to mention that possible future developments of the White Rabbit switching devices could make use of the sole 10 GbE technology. This would reduce the number of Level 1 switches needed for Phase 1 detector to about 30 units, requiring their arrangement into only one standard rack .

Such improvements are really important since the reference block (Phase 2 detector) is 6 times larger.

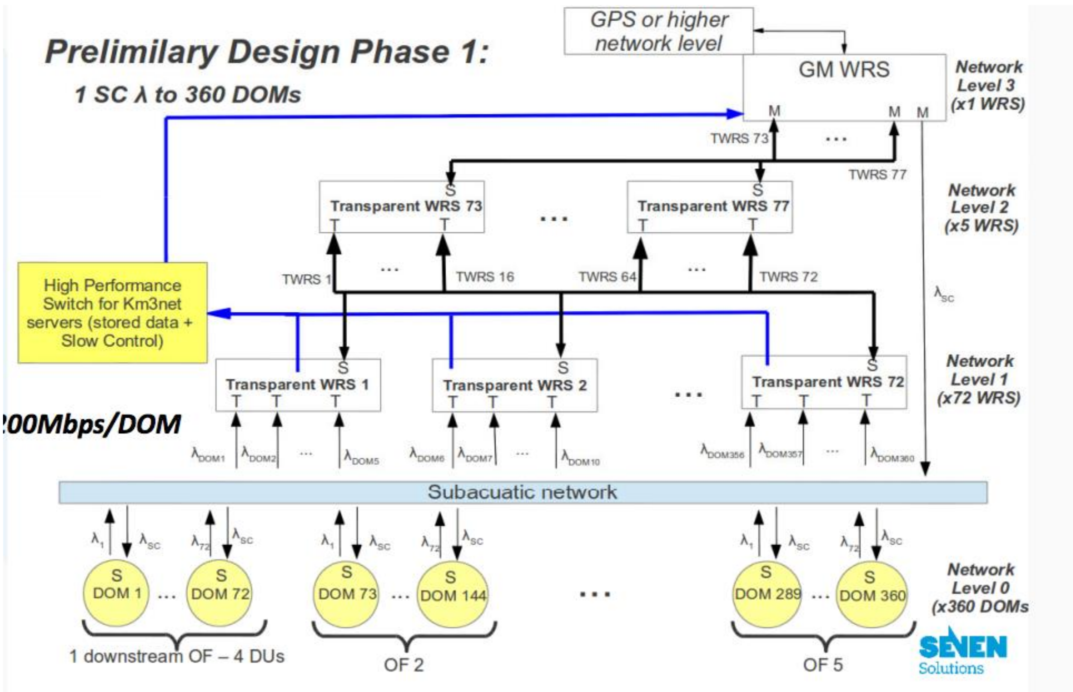


Figure 6.7. The White Rabbit switching infrastructure as Front End for the incoming data from off-shore.

The blue arrows sketched in Figure 6.7 represents the uplink connections from the Level 1 White Rabbit switches towards the star center switching facility used for the TriDAS. An intermediate level of stacked uplink devices would be useful to gather the 110 channels into a reduced number of 10 GbE connections, before accessing the DataQueue servers, as sketched in Figure 6.8.

6.1.1 TriDAS Farm dimensioning

The optical TriDAS requirements in terms of computing power are the most severe, because of the very large data-stream to handle. For Phase 1, with referring to Table 6.2, we could consider 10

DataQueue servers (each one connected to ~ 50 CLBs and able to withstand the incoming throughput of 1-2 Gbps with worse bust-assumptions than even those conservative of Table 6.2).
For Phase 2 the DataQueue number could be enhanced by a factor 3-4.
From a preliminary benchmarking of the trigger peformance requirements, the DataFilter resulted number is of about 10-15, for Phase 1, while it becomes much larger for Phase 2, rising to about 100 servers.

The EM is a unique process on a single machines. The *Control Unit* could be distributed on different machines but not exceeding 5 servers.

Eventually, 3 or 4 racks could be used to arrange the servers

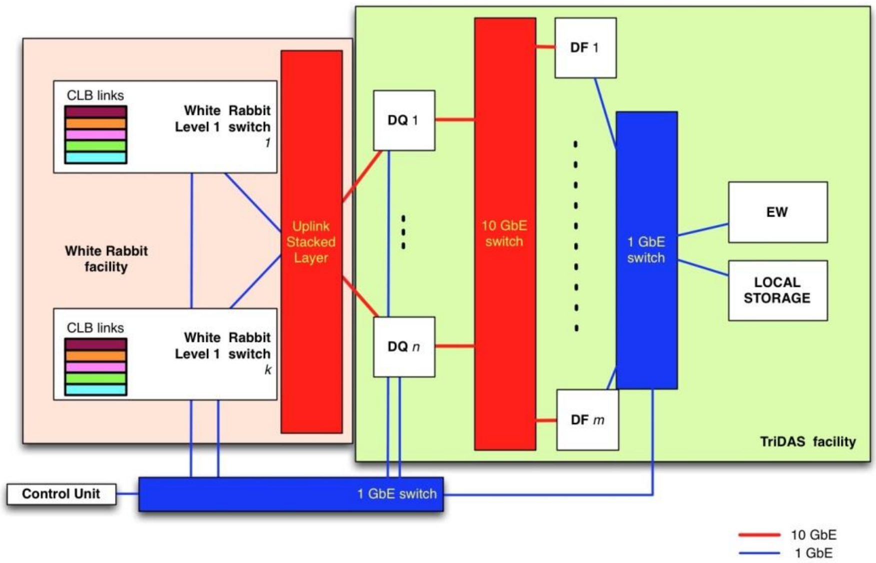


Figure 6.8. The possible design for the DAQ Network from the White Rabbit Level 1 switches to the TriDAS LAN.

6.1.2 Storaging for Phase 1 and Phase 2

Table 6.4 shows the estimations of the selected throughput arriving to the Event Writer process, and the extrapolation in terms of TB/day for the data to be temporary kept locally in the shore-station. Similarly to what has been reported for the 8 Towers detector, the table shows also the prevision of the yearly stored data.

Detector	μ tirgger rate (Hz)	event window size (μs)	Selected throughput (MBps)	Local Storaging (TB/day)	Global Storaging (TB/y)
Phase 1	50	6	1.7	0.14	50
Phase 2	300	6	17	1.4	500

Table 6.4. The expected post-trigger rates for both Phase 1 and 2 detectors.

As for the case of the 8 Towers, the above computations are based on additional assumptions concerning the muon trigger rates and the event window size. Also in this case such assumptions are conservative.

Besides the expectation for the amount of selected physics data it is important to evaluate the amount of *non*-data information, i.e. the values provided by the various sensors and devices on-board of the CLBs.

The case for Phase 2 is considered. It is assumed the size of 128 bytes to one monitoring message carrying the complete snapshot of information for each of the 2160 CLBs. Willing to log information with the rate of 0.1 Hz, the yearly rate of non data is ~ 800 GB/y, which is a quite small rate, easy for a DataBase to withstand. In addition to this, we must consider the summary information with the effective measured optical hit-rate monitored at a rate of 10 Hz (i.e. at any timeslice). Assuming to use 1 byte to store the hit-rate for any 3" PMT, we get an additional throughput of 20 TB/y which is more than 1 order of magnitude less than the recorded physics data.

In the end, also for KM3NeT, a local temporary storage resource of 10 TB is suitable for the request of both Phase 1 and Phase 2 detectors.

6.2 Monitoring

The monitoring as well as the quasi-online analysis processes and the Control Unit are distributed as web applications and handled by means of web browsers.

7. Database support to construction and integration management

The KM3NeT Database (shortcut as DB in the following) provides the information handling infrastructure for all the activities related to the construction of the detector, namely:

- tracking and documentation of all components, organized in a functional hierarchy (Product Breakdown Structure, shortened as PBS) and in a physical containment hierarchy (Container Mapping);
- tracking of construction and integration, at least on a daily basis;
- documentation of testing and quality assessment procedures and their implementation on each component;
- documentation and management of calibration parameters obtained by testing activities.

The goals of the DB project in KM3NeT are:

- detailed bookkeeping, useful at run time and analysis time;
- proactive information circulation for construction management.

Such goals are pursued by establishing a common platform that is able to accommodate the information for both the “String/Multi-PMT DOM” technology and for the “Tower/Single-PMT OM” technology. All the information flow for the latter is fully conformant to the scheme set up for the former, and the two co-exist in a harmonic way.

7. 1 Functional and physical structure documentation

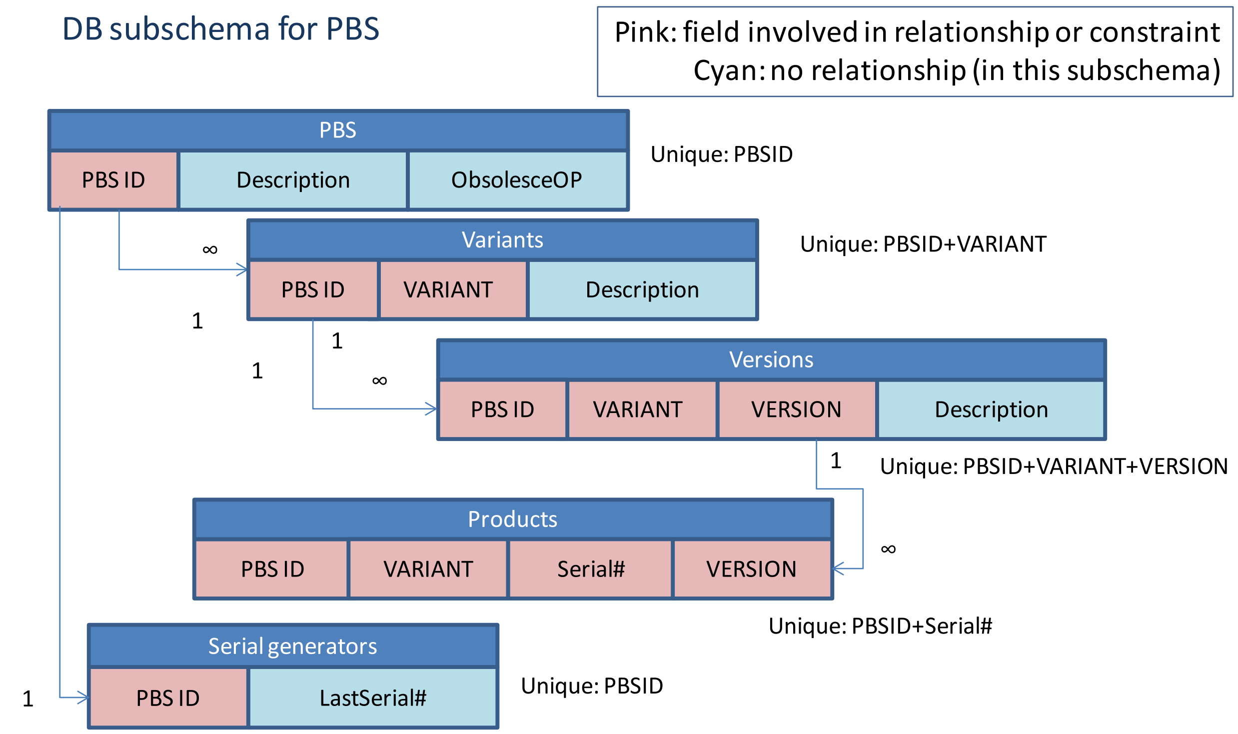
The PBS defines all the functional components of the KM3NeT data collection and processing facilities. It is documented and maintained on the DB. The PBS has a tree-like structure, with numbered root categories; the ones that are most relevant to the detector in Capo Passero are:

1. Onshore Infrastructure
2. Deep Sea Network
3. Detection Unit
4. Calibration Unit
5. Sea Operation System
6. Production and Assembly

Each root category has sub-categories or elements inheriting their numbering from the parent category, with the scheme *a.b.c.d*.... (being *a*, *b*, *c*, *d*, ... numbers) that can be extended as needed. Each element can have multiple variants (to account for functional differences) and versions (to accommodate functionally identical or similar products that evolve over time). Any element in the logical tree structure is uniquely identified with PBS/VARIANT/VERSION (e.g. 2.3.2.6.2/DEFAULT/1). The entries corresponding to purchased components are accompanied by one or more documents, stored in the DB, containing the technical specifications; those corresponding to products of integration actions are accompanied by integration instructions and drawings, in such a way that no ambiguity can arise concerning the production and the specifications of each such component. The DB tables also host all the accompanying documentation files, either in PDF format (for entries requiring a single document) or as compressed files (ZIP format or equivalent) containing multiple documents for one entry.

Every physical item of a type that is defined in the functional hierarchy has a Unique Product Identifier (shortened as UPI) with the syntax #PBSID.SERIAL# (e.g. #2.3.2.6.2/DEFAULT/1.6#). The serial number is a sequential number that identifies items with the same PBS (not PBS/VARIANT/VERSION) that are created. The UPI is unique throughout all the KM3NeT sites, and even objects/devices to be deployed in geographically different sites cannot have clashing UPI's.

The logical structure of the DB tables related to PBS and product documentation is shown in the following sketch:



PBS entries can be added by DB administrators upon request of the Technical Coordinator and people explicitly delegated for the purpose. PBS/VARIANT/VERSIONS can be directly created by the Technical Coordinator and explicitly delegated people. The insertion of new elements into the PBS hierarchy is logged by filling specific fields recording the time and person related to the action.

The physical containment relationships ("Container Mapping") are defined in the DB (in addition to being specified in the assembling instructions) in tables that are filled by DB administrators, the Technical Coordinator, or persons delegated by the TC on purpose. Each composite object can contain elements of several types and a well-defined number of "slots" according to the multiplicity of each type. Correspondingly, the physical description table in the DB contains several records, one for each slot, as in the example sketch:

1.2.3/DEFAULT/1				
1.2.6.7/DEFAULT/1 Slot #1	1.2.6.7/DEFAULT/1 Slot #2	1.2.6.7/DEFAULT/1 Slot #3	1.2.9.2/DEFAULT/1 Slot #1	1.2.9.2/DEFAULT/1 Slot #2

The functional description, the physical description, the technical specifications and/or the assembling instructions completely define each object type in the KM3NeT detector.

More information about the details of PBS and UPI can be found in the defining document by Kay Graf at https://docs.google.com/a/km3net.de/file/d/0B6l8SNtndcwaRGEwMDB5NzdTLUE .

7.2 Physical object documentation

Physical objects ("products") that build up the detector, corresponding to one of the functional categories of the PBS, can be entered by the Technical Coordinator and persons delegated on purpose. For each product, at least the following information has to be filled:

- UPI
- creation time
- person responsible for data insertion (which should be the same who is responsible for purchase or production)

For purchased products, also the vendor and the bill identifier are required. Products can have accompanying documents (single PDF or ZIP or equivalent containing multiple files) reporting their performance as assessed by the producer. However, acquisition of information in this shape is discouraged and must be considered the last solution, when nominal performance/calibration data are not available in a format that can be easily processed by computer programs, such as spreadsheets, CSV/DAT/TXT ASCII files, etc.. Such information is supposed to be stored in DB tables set up on purpose, so they can be accessed programmatically by the run control software during data acquisition and by the analysis software when processing offline the acquired data. Therefore, storing human readout-oriented documents is to be considered as the "backup solution" when technical limitations by the producer of a component prevent feeding data in more efficient formats. Product characterization and performance assessment is also foreseen at different stages; when this occurs, both the producer-provided datasheets and the results of the calibrations are stored in the DB, the latter overriding the former for the purposes of run control and data analysis.

Composite objects, i.e. those that are built as the result of the integration process by assembling several objects together, have corresponding entries in the DB to document and monitor the process of integration. As all operations that are supposed to have a non-negligible time span (ranging from minutes to days), integration operations are recorded in the DB with their start date/time, end date/time, a location, a responsible person and an overall report on the operation, at least distinguishing successful operations from failed ones. The integration processes of several objects can be bundled together in a single operation (e.g. working day). Each integrated object has its own final status code. This allows also tracking the cases of object that, after integration, do not pass quality checks and have to be partially dismantled to replace defective components: the DB will track the full history of assembling, testing, disassembling, replacement and re-testing to finally pass quality checks. Each component of a composite object is documented to fill a well-defined slot in the Container Mapping structure. It is possible, for the run control software as well as for the analysis software, to identify a logical location in the detector with an object through its UPI (e.g. PMT #4 of floor #3 of tower #2 → #3.4.2.3/IT:TOW/1.106#); the related test results and calibrations are stored in the DB and can be accessed at any time.

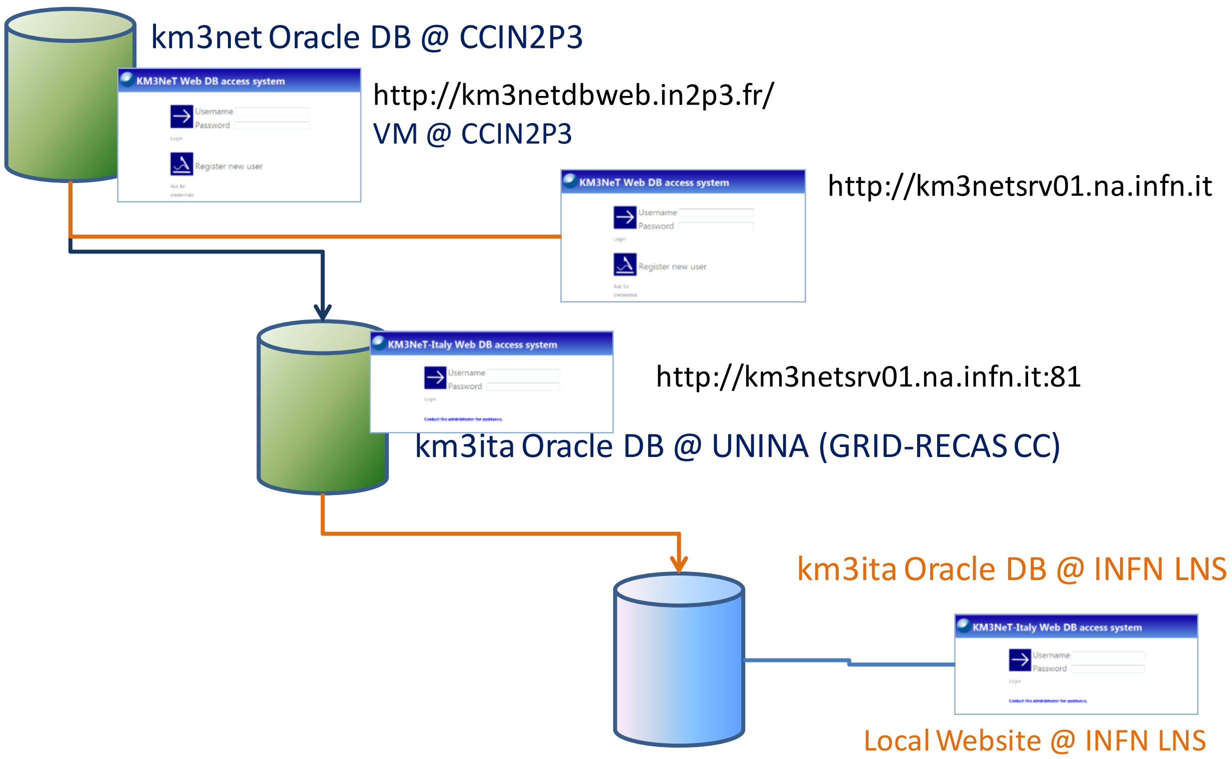
In order to make product identification easy and error-safe, it is foreseen to use barcode or QR identification in all cases where there is enough room on the object surface to accommodate a sticker or a printed code. Objects with undefined shape (e.g. gel) will be identified, when possible, by the batch number of the producer. Integration and testing stations will be equipped with barcode or QR printers/readers.

Each integration station will be equipped with at least one tablet PC to document the progress of the integration. The tablet PC will run a custom developed app that is in continuous contact with the DB using HTTP(S) towards a Web server interface. The app will be used to notify that integration has started on a certain product, to identify its components and the physical "slots" where they are assembled and the end of the integration process. The person that manages the app on-the-field is identified with a login PIN, and his/her identity is logged on the DB for each operation. At the end of the integration for each product, one or more pictures are taken and sent to the DB via the Web interface. Barcode and QR reading software is integrated in the app to make usage easier. The app will also make assembling instructions, drawings and other available information (e.g. mechanical adjustment information, notes) from the DB available at any time on-the-field. To prevent interruption of the production in case of network unavailability, the app will also be able to work with cached information, synchronizing itself automatically with the DB as soon as the network connection is restored. Another purpose of pictures is allowing error-correction "backwards in time": when an error is discovered on an object that cannot be disassembled (e.g. because it has already been deployed on the seabed), pictures can allow *a posteriori* correction of the information in the DB (e.g. if the mounting slot or product UPI is different from what was declared during production).

Testing stations (test-benches) are interface with the DB, working on the HTTP(S) protocol towards a Web server interface. Data are downloaded by running computer queries that can also be reproduced by Web pages (to make debugging and checking easy). All the testing activity is supposed to run even without network connection, using cached information. At the end of the testing session, the information stored locally as files will be uploaded to the DB via the Web server interface. As in the case of integration, the start/end date/time, the location and the responsible of the test-bench are documented, along with the results of the test. When non-atomic data are being worked out (e.g. calibration numbers, curves, etc.), their results will be stored in suitable DB tables, able to accommodate complex data types in computer-usable formats.

7.3 IT infrastructure

The basic elements of the IT infrastructure that supports integration and testing tracking and documentation have already been introduced. The following sketch lists the machines and services, identifying those that are already installed and working with their IP address or DNS hostname.



The infrastructure is integrated with the KM3NeT DB hosted at the Lyon CC, denoted as "km3net" DB.

The "km3ita" DB, currently hosted in the RECAS CC at the University of Napoli, contains a subset of the information of the "km3net" DB, and periodically synchronizes with it. "km3ita" has a complete mirror hosted at the Catania INFN site of LNS. Such redundant scheme not only protects data (which are however supposed to be periodically backed up to long-term storage media), but also allows continuous operation in case of network troubles at one of the sites, or in the network path towards it.

In all cases, DB access occurs exclusively through a custom Web server interface, developed and maintained on purpose. The Web interface ensures that no malformed SQL statements be issued by non-experienced users; it also optimises access to the DB by sharing resources. The Web server provides the users with a graphical user interfaces, but also exposes pages designed for machine-to-machine communication to feed the DB with data and retrieve them for usage in run control and analysis programs.