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# On line monitoring of the power control and engineering parameters systems of the NEMO Phase-2 tower

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**Abstract**

The NEMO Collaboration is presently carrying out an intense activity on “NEMO Phase-2” project for the realization of an underwater infrastructure on the deep-sea site of Capo Passero including a fully instrumented 16 storey tower. In this paper the design of the electrical power control system and of a system for the monitoring of some engineering parameters, useful to study the dynamical behavior of the structure, are presented. The proposed architecture is strongly modular and flexible. The entire architecture is described with a special focus on the electrical parameters monitoring, protection system and on the sensors fusion algorithm implemented to deduce the attitude through MEMS accelerometers and magnetometer sensors.



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## 1. Introduction

The NEMO Phase-2 project, presently under construction on the deep-sea site of Capo Passero (Sicily), will include an underwater infrastructure, comprising a 100 km electro-optical cable and a 10 kW DC/DC converter, and a fully instrumented detection unit of the type developed by the NEMO collaboration[1][2].

In this paper the power control system for the NEMO Phase-2 apparatus is described.

The main tasks of an underwater power control system are the control, monitoring and protection against over-current and over- and under-voltage of the electronics boards installed underwater.

The system integrates in a unified hardware structure both the functionalities needed to control the power

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feeding system as well as a dedicated inertial-magneto system to control the dynamics of the tower mechanical structure during operation.

The system has been designed taking into account the experience gained with the NEMO Phase-1 [3]. In particular some strategies have been adopted: redundancy has been implemented to increase the system reliability; all the electronics of the power control system has been validated to work under pressure in oil bath, thus eliminating the need of high pressure resistant vessels; the communication for data and control of the power system uses copper twisted pairs.

## 2. NEMO Phase II power distribution and control system

A scheme of the power feeding system of the NEMO Phase-2 infrastructure, under construction on the deep-sea site of Capo Passero [4], is shown in fig. 1. It consists of the following elements:

- A Power Feeding Equipment (PFE), located in the shore station, with a 50 kW AC/DC converter operating at at 10 kV;
- A 100 km DC cable, manufactured by Alcatel, that can be operated at up to 10 kV;
- A deep-sea cable termination assembly including a Medium Voltage Converter (MVC) from 10 kV to 375 V;
- The tower base power system that allows the monitoring of the 375 V supplied by the MVC and the on/off switching of the full tower;
- The tower power system distributed in the sixteen Power Supply Modules that are present on each tower floor. Each module allows to feed the needed voltages for the floor electronics as well as monitoring of voltages and currents.

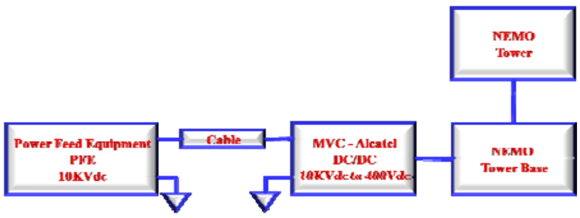


Fig. 1 Architecture overview of the NEMO Phase-2 power distribution system.

The architecture of the power control data transmission is based on an optical fast Ethernet [5] link from the shore station down to the tower base. At the tower base level a conversion systems to serial RS485 has been installed. Communication towards the tower floors is implemented on a twisted pair along the tower backbone.

## 3. Power Control System

The electronics of the power control system are hosted inside a Power Supply Module (PSM) that in turn is contained inside the Protective Oceanic Device (POD) vessel present on each tower floor. The PMS is a light mechanical container filled in oil and pressure compensated. The electronics of the power control system were, therefore, designed to withstand pressures up to 400 bars.

The electronics of the floor power system are

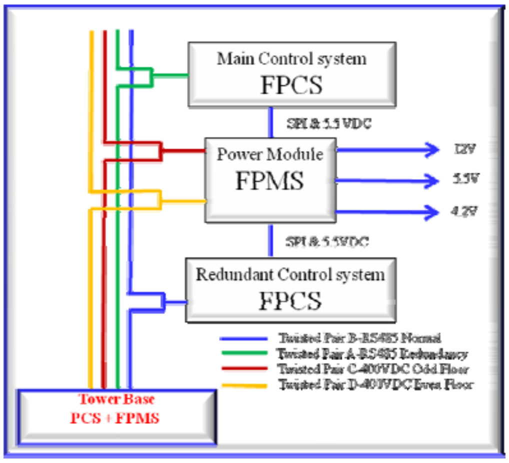


Fig. 2 Power Module System wiring

composed by three boards: a Floor Power Module System (FPMS) and two Power Control System (PCS). The PSM wiring scheme is shown in fig. 2.

Three separately section have been included in the PCS board to execute the following tasks:

- Power control system;
- Inertial-magneto monitoring system section;
- Optical isolation serial interface;

The FPMS (fig. 3) is an electronics board that performs the following tasks:

- Soft start for limiting the current at system start up;
- Conversion of the DC supply from 375 V to 12 V, 5.5 V and 4.2 V;
- On/off Switching of the power feeding lines;

The PCS board allows to control all the main electrical parameters of the system. The main functions performed are:

- Monitoring of the electrical parameters at each feeding power line;
- Monitoring of environmental parameters such as temperature and pressure inside the PSM;
- On/off switching of the power supply on the high voltage and low voltage lines;
- Setting of voltage and current safety thresholds.

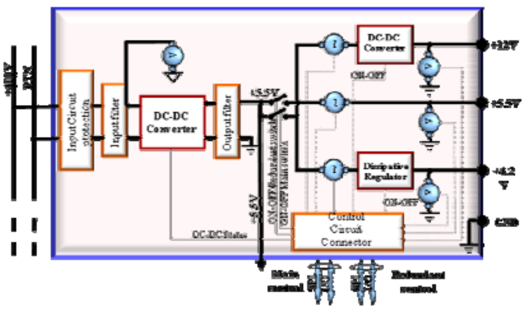


Fig. 3 Layout of the Floor Power Module System

Protection against over-current is performed locally based on the threshold value set by remote. Notification of a fault state is transmitted on shore via the dedicated data transmission system described above. This safety system can be disabled to override possible sensor malfunctions.

Communication between the PCS boards and the FPMS board is performed via a SPI bus.

The shore power control station includes a PC running a friendly user interface.

The system is presently under development. A laboratory test bench has been set-up to check the system performance. Its layout is shown in fig 4.

The baud rate of the serial RS485 link is 115200 bps. The delay introduced by the data transmission chain and the electronics board has been measured to be 192 ms. This corresponds to a 5 Hz update rate for the full tower.

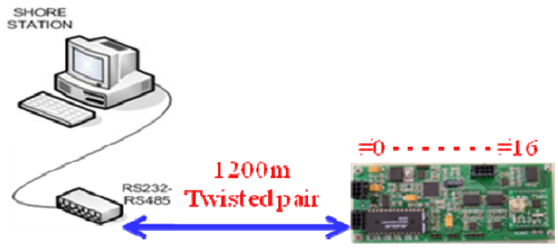


Fig. 4 Layout of data transmission test bench

## 4. Inertial-magneto monitoring system

As already mentioned the PCS board also integrates a inertial-magneto system to monitor some engineering parameters of the tower, such as: depth of each floor; roll, pitch and heading of each floor; acceleration along three axes.

Information coming from Micro Electro-Mechanical Systems (MEMS) tri-axial accelerometers, tri-axial magnetometers, temperature sensor and pressure sensor, are integrated by a sensor fusion algorithm, including a Kalman Filtering technique to reduce noise.

This strap-down, low cost inertial system uses the following sensors:

- Freescale MMA1220D accelerometer for the Z axis;
- Freescale MMA2260 accelerometers for X and Y axes;
- PNI MicroMag3 3-Axis magnetic sensor module;
- 2nd order hardware filters for analog sensors filtering;
- DS1820 temperature sensor.

The PCS board is shown in fig. 5.

The algorithm implemented allows to determine the compass angle from the projection of the tri-axial magnetic measurements on the level plane surface using the roll and pitch angles obtained from the tri-axial accelerometer [6].

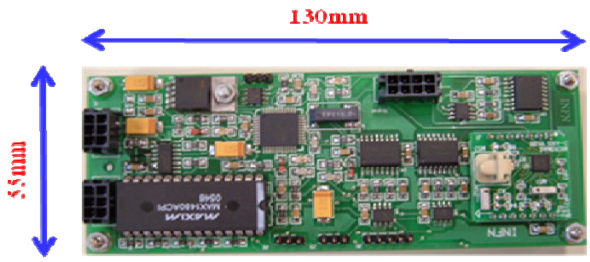


Fig. 5 The Power Control System board.

## Conclusions

A dedicated system for the power feeding control of the NEMO Phase-2 underwater detector has been designed. The system integrates both the functionalities needed to control the power feeding system as well as a dedicated inertial-magneto system to monitor some engineering parameters of the mechanical structure.

The full system has been tested in laboratory and is now ready for integration in the NEMO tower.

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