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THE OPERA POWER DISTRIBUTION SYSTEM

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Abstract

We describe the power distribution system designed and implemented for the electronic subdetectors (scintillators, RPC/XPC/VETO, drift tubes) and facilities (BMS, DAQ, water cooling plant, magnets) of the OPERA experiment. This note is intended as a technical description of the system and a reference for on-call experts and shifters.

1 Introduction

The power distribution system of OPERA [1] has been designed paying particular attention to scalability and fault tolerance. The general layout was prepared by the Electronic office of LNGS and by SEA-LNF. The executive drawings, certification of compliance with Italian safety rules [2] and installation have been carried out by an external firm (Arcobaleno s.n.c., L'Aquila, Italy).

The system was completed in March 2006 and has been fully operative several months before the startup of CNGS. At present, it serves all the electronic subdetectors (scintillators, RPC/XPC/VETO, drift tubes) and facilities (BMS, DAQ, water cooling plant, magnets) of the OPERA experiment.

In this note, we provide an user-oriented description of the system and give technical information for maintenance and operation in case of faults. The description includes the main switchboard in Hall C (Sec.2), the power distribution to the electronic detectors (Sec.3), magnets (Sec.4), BMS, to the water cooling plant and the DAQ barrack (Sec.5). A brief Appendix on the OPERA UPS is also given.

2 Main power switch in Hall C

Electric power to OPERA is provided by LNGS through a switchboard located at the entrance of Hall C (Fig.1). This cabinet is divided into three sections. The first one comprises all the users directly connected to the main line power ("mains") of the underground labs. These users are not protected by glitches and power cuts and no critical services should be connected to this sector of the cabinet. The second section mainly powers the magnets [3] and, depending on the position of the cabinet knobs, it can be put either under mains or under UPS [1]. At time of writing, both magnets are operated under UPS. Finally, the third section is always operated under UPS and powers all critical users. The whole system is grounded through a TN-S [4] earthing system: the neutral (N) is connected to ground at the cabinet while the protection earth (PE) and N are separate conductors that are only connected near the power source. In December 2006 additional spare breakers (40 A) have been added to the sections under mains and under UPS and the present layout of the cabinet is as follows:

- **Section under LNGS main power line** Currently the only user is the chiller for the water cooling system. Its maximum power is 22.6 kW. Five 3-ph spare breakers are available.

[1] In principle, all sections can be put under UPS; however, for OPERA it is not foreseen to change the source of section 1 and 3. A brief description of the OPERA UPS is given in the Appendix.

Figure 1: Main cabinet at the entrance of Hall C.

- **Section under UPS (switchable to mains)** This section is used for the two magnet power supplies (one breaker per magnet). Typical consumption of the magnet, including the efficiency of the PS is 27 kW. The installed power is 80 kW per breaker. An additional spare breaker is also available.
- **Section under UPS** This is the most busy section; it includes all the detector electronics (one breaker per spectrometer labeled "Rivelatore 1" and "Rivelatore 2"), the two BMS modules ("BMS 1" and "BMS 2"), the source for the pump system located on top of the experiment ("Pompe") and for the DAQ barrack located behind Magnet 2. Two 40 A spare plugs are available.

3 Power lines for the detectors

The buses that start from the "Rivelatore 1" and "Rivelatore 2" outlets feed most of the electronics for OPERA. All crates related with the DAQ, TT, RPC/XPC, HPT and Veto are sourced from these lines. Hence, such sub-system is highly partitioned to guarantee fault-tolerance and scalability. The block diagram of the system is shown in Fig.2. As two separate lines have been used to power the two supermodules (SM), from here on we will describe the system for a single SM.

The first block of the chain is the “main power switch” (“quadro di distribuzione”, Fig.3). The switchboard allows to power-on half apparatus and should be turned off only in case of emergency or for maintenance purpose. It is instrumented with a voltage and current monitor and a main selector to isolate the whole sector from the rest of the system. All lines from and to the main power switch are three-phases.

The second block of the chain are the “power plugs” (“quadri prese”, Fig.4). The plugs allow to connect the lines to power each single rack. Turning off a rack using the “power plugs” switchboard is possible, but we discourage this procedure as the user could accidentally cut power to other racks. Beyond segmentation, the power plugs provide monophase outlets to the racks. A label (S,T or R) located above the 1-ph plugs indicates the phase that is connected to the neutral to obtain the monophase source. Two three-phase plugs (bottom red of Fig.4) are also available and are currently connected to the racks for the drift tubes.

The final blocks of the chain are the rack “power distribution boxes” (Fig.5). They are located inside the front-end racks and can be fully managed by the final user. Each box provides 12 plugs (located on the back of the box itself) and can deliver up to 1.5 kW. Besides the ON/OFF switch each box is instrumented with a display to measure the delivered current and with an emergency power cut-off button (Fig.5). The switches visible in the figure are (from left to right) the breaker driven by the temperature/smoke alarm, the magnetothermic breaker (overcurrent protection) and the differential earth leakage current breaker. The transformer on the right provides 12 V DC for the smoke/temperature alarm system. The temperature at which the system intervenes can be set from a knob located just after the plugs (Fig.6). The final user will typically operate only onto the power distribution boxes.

Strong network perturbation can open breakers also at the main power switch and at the power plugs. If the source of failure is removed and the switch at the distribution box does not close, check the corresponding breakers at the main power switch or plug. Note also that lights are directly connected to the boxes without dedicated lines or switches (to switch off the light, it is necessary to remove the plug from the outlet). Emergency lights are positioned along the Hall and maintained by LNGS services.

4 Power lines for magnets

The magnet power supplies are by far the most demanding users on top of the platform. Specific three-phase (no neutral) lines are drawn from the main cabin to the power supply.

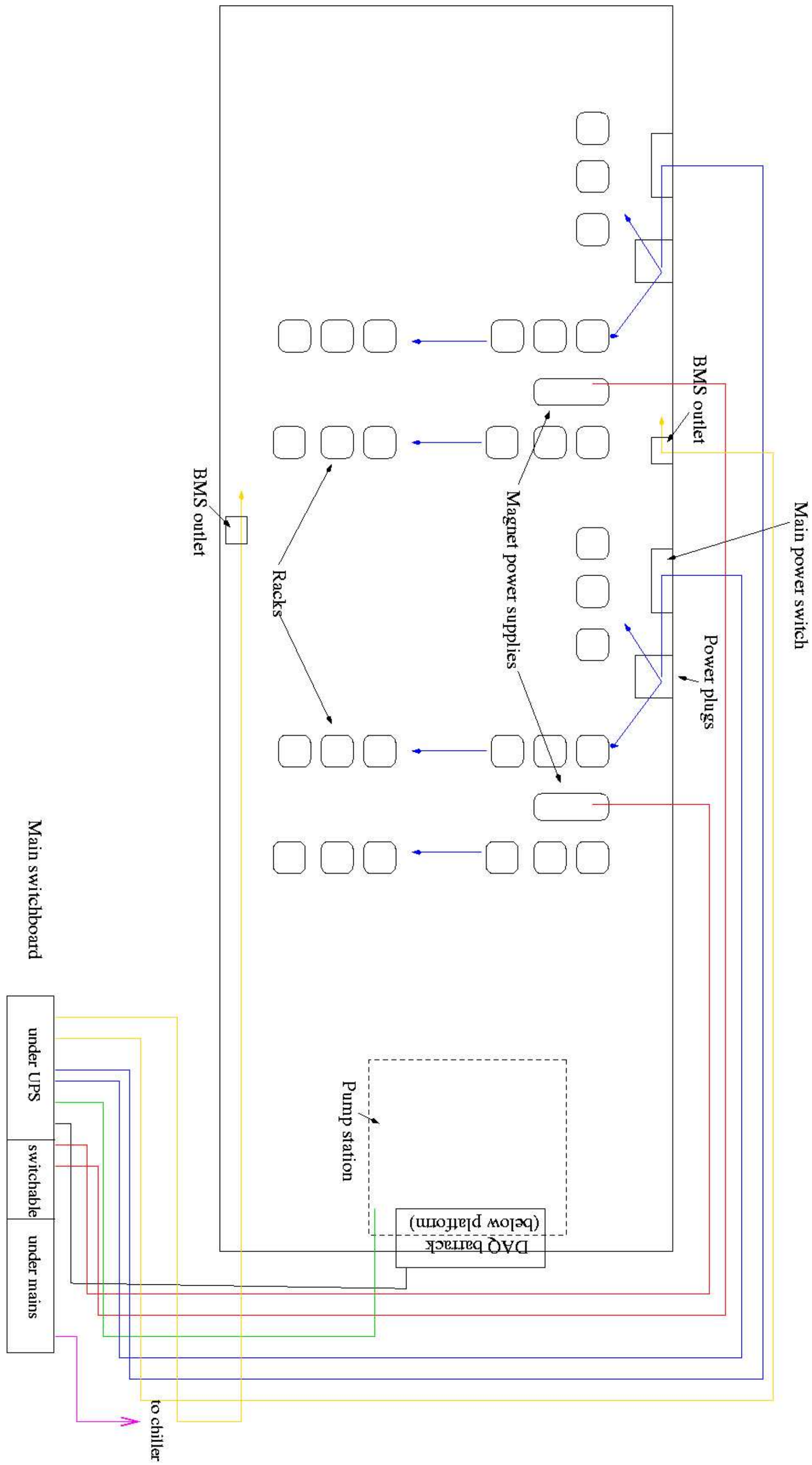

Figure 2: Schematics of the OPERA power distribution system.

Figure 3: The main power switch.

Presence of the phases can be inferred on the back of the power supply (Fig.7) from three red lights (R, S and T phase). When the power supply is on, a monitor located near the lights provide a measurements of the absorbed current and the voltage among phases. As mentioned above, the section feeding the magnets can be sourced either by the UPS or by the mains. Passing from one to another can be done by LNGS operators at the main cabinet without interruption of service.

5 Lines for the water cooling system, BMS and DAQ barrack

The water cooling plant is mainly located on top of OPERA (the pump station is shown in Fig.8). The chiller, however, is outside the Hall C. A cabinet positioned near the pump station is supplied by a cable starting from the UPS section of the main switchboard (MS). This cabinet provides power to the pumps, fluxmeters, monitor of conductivity and the relays that switch off the magnet power supplies in case of failure. A dedicated line starts from the non-UPS section of the MS, runs alongside the Hall C and reaches the chiller located at the end of the bypass between OPERA and Borexino.

Each BMS has a dedicated line from the UPS-section of the MS up to a small cabinet located onto the platform near the handrails. This cabinet (Fig.9) provides as output

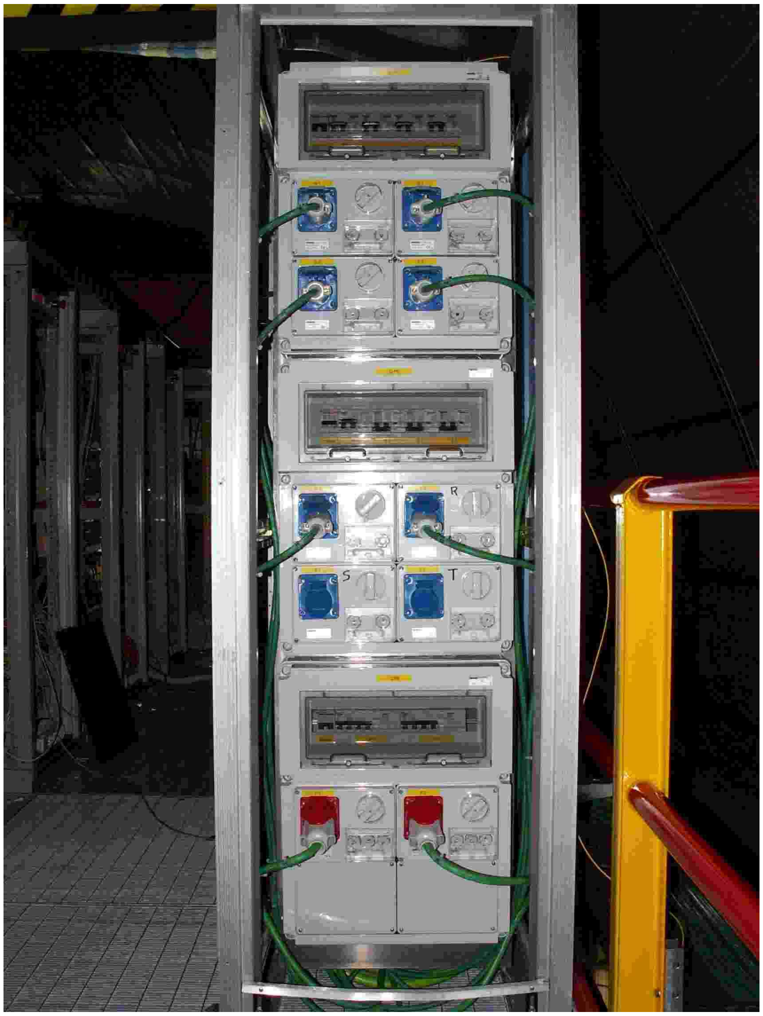

Figure 4: The power plugs.

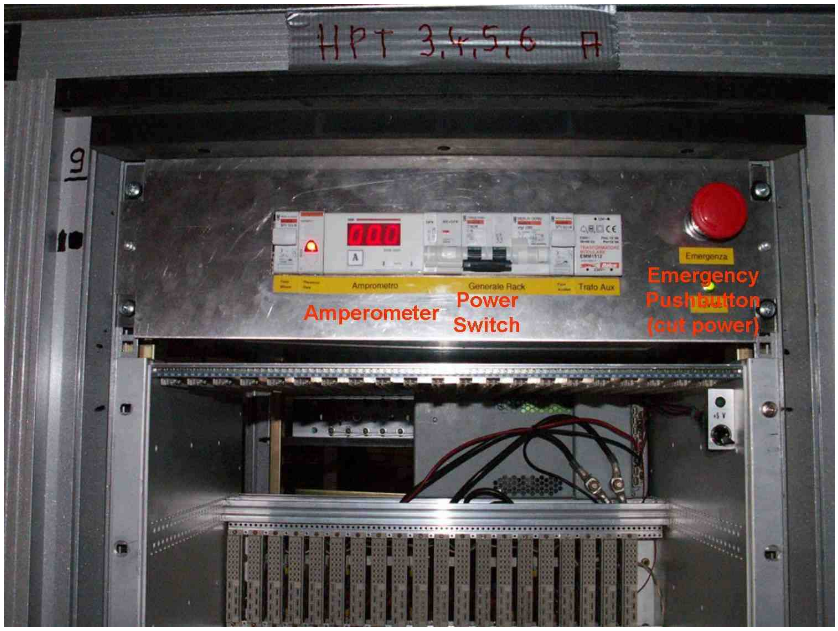

Figure 5: Front view of the power distribution boxes. The plugs (not visible) are located on the back.

Figure 6: Temperature and smoke sensors. The knob allows the regulation of the overtemperature alarm threshold. The back of the distribution box and the corresponding plugs are also visible.

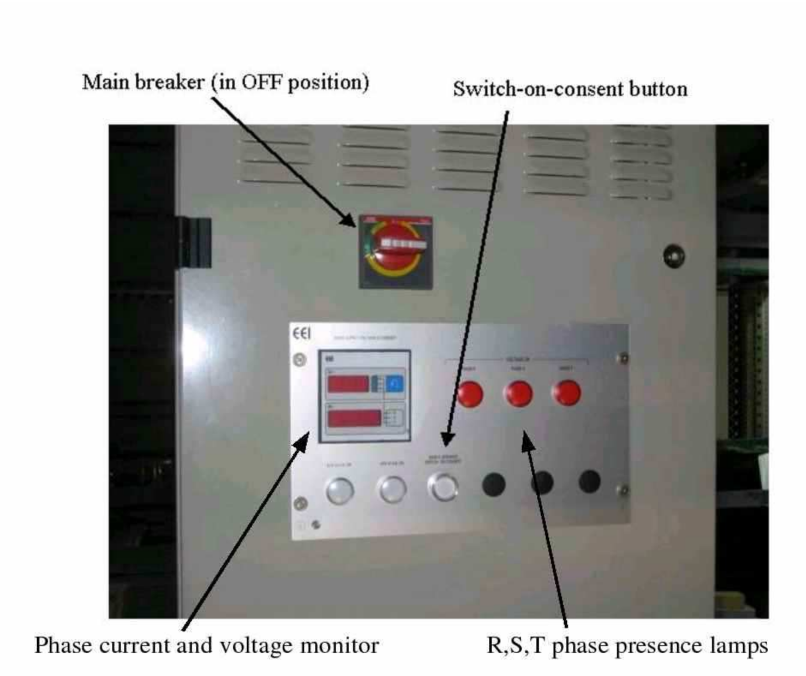

Figure 7: Back view of one of the two power supplies for the magnets.

the 1ph and 3ph lines necessary to the operation of the BMS electronics and motors. Also the DAQ/MMS barrack located on the back of the experiment is fed by a dedicated line from the UPS section of the MS. Power distribution plugs have been built inside the barrack sourcing the DAQ and MMS racks.

6 Additional informations

Even in running conditions, operations on the OPERA UPS and the main switchboard must be carried on by the LNGS technical division. An on-call expert is available outside working hours. On-call experts of the various subdetectors should be aware of the position of the lines sourcing their systems and they can refer to this document for details. Shifters can operate only the power distribution boxes located on top of the racks, possibly under the supervision of the subdetector on-call person. Further informations can be found in the online shift resource site (currently opera.pd.infn.it/dokuwiki) and in http://www.lnf.infn.it/self/opera/PowerDistribution/

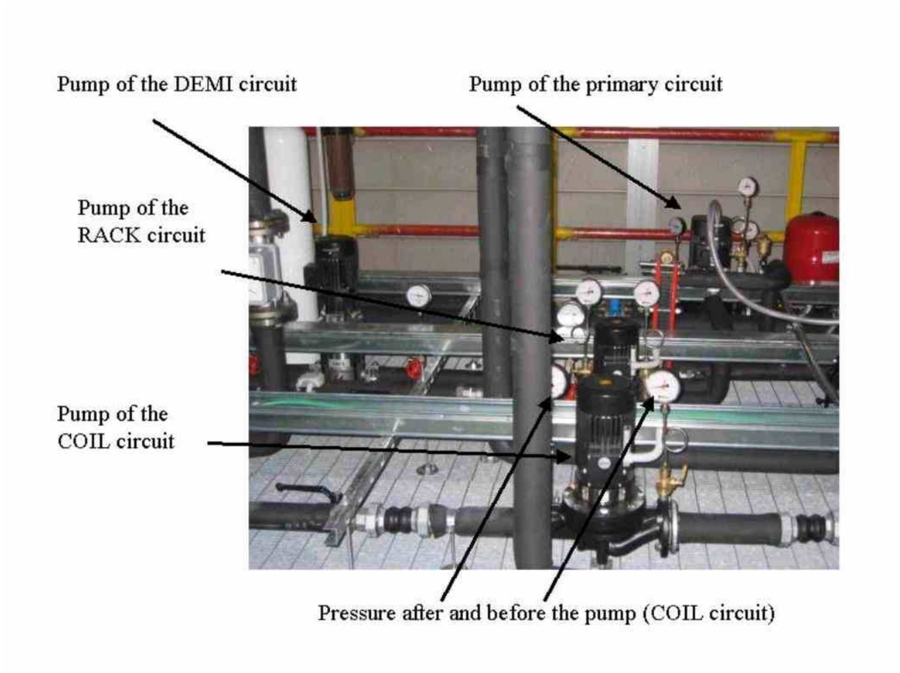

Figure 8: The pump system on the top platform.

Figure 9: One of the two BMS cabinet located on the top platform.

Acknowledgments

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Appendix: the OPERA UPS

The OPERA experiment needs continuous operation and protection from power line anomalies (phase interruption and glitches) for several subdetectors. A large uninterruptible power supply has been made available to OPERA after the dismounting of MACRO. The MACRO/OPERA UPS was manufactured by Piller Power Systems GmbH in 1991. It provides service continuity up to 250 kVA (about 200 kW at $\cos\phi = 0.8$) for ~ 15 minutes. A major revision of the system has been carried out in autumn 2006 (substitution of several PLC's and condensers). The system is under the responsibility of the LNGS technical divisions. It is currently shared by the subdetectors in Hall C (TT, DAQ, RPC/XPC/VETO, HPT, Magnets, Pumps, BMS) and the BAM which is located in the bypass between Hall A and B and it has an independent power line (not described in this document). A connection of the chiller located in the bypass between OPERA and BOREXINO is also foreseen.

References

[1] M. Guler et al., *An appearance experiment to search for $\nu_\mu \to \nu_\tau$ oscillations in the CNGS beam* CERN/SPSC 2000-028, SPSC/P318, LNGS P25/2000, Jul. 2000.

[2] In Italy, the general principles for installations of electric plants are defined in the law n.46/90 (5 March 1990) and technical requirements are detailed by the "Comitato Elettrotecnico Italiano" (CEI norms). Most of these norms are actually European standards (CEI EN standards). Additional informations can be found in www.ceiweb.it.

[3] M. Ambrosio et al., *The OPERA magnetic spectrometer* IEEE Trans. Nucl. Sci. **51** (2004) 975. F. Terranova et al., *A briefbook to operate the magnets in local mode*, Opera Note.

[4] IEC 60364-1: Electrical installations of buildings Part 1: Fundamental principles, assessment of general characteristics, definitions. International Electrotechnical Commission, Geneva.