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Specification for the new power supplies of the MEBT steerers at CNAO, including 12 month warranty

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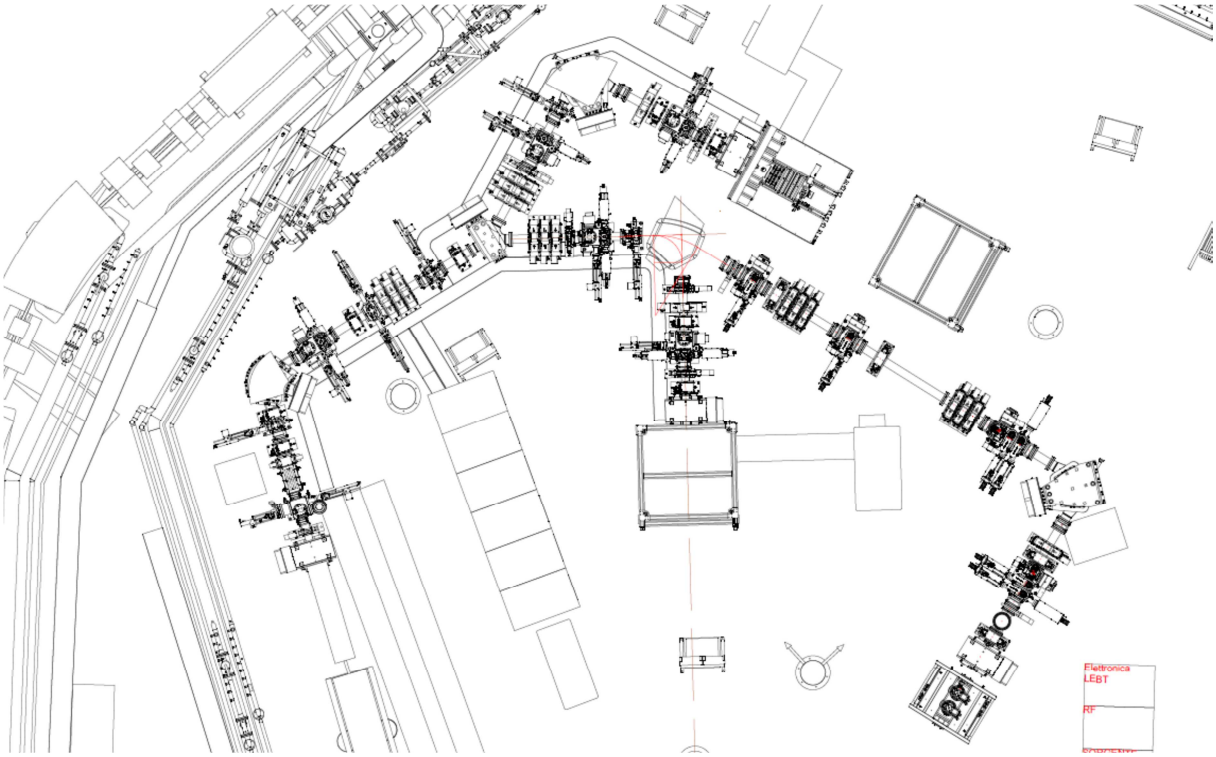
INDEX

1. Introduction

CNAO Foundation, as the Lombard research institution leading the INSPIRIT project, conducted in partnership with INFN and PMI Hifuture, (PROJECT ID 1161908 CUP E18I19000180007) funded by the Lombardy Region under the POR FESR 2014-2020 Call Hub Research and Innovation, has among its project objectives the realization of an innovative source capable of producing new ionic species that will be accelerated by the synchrotron and directed to the experimental room to be made available for research and industrial activities. A synchrotron, capable of accelerating both light ions and protons, is the fundamental tool of the CNAO (National Center for Oncological Hadrontherapy), the Italian center dedicated to the therapy of tumors with hadrons, in Pavia, Italy.
The machine consists of two ion sources, a linear accelerator (linac) for protons and carbon ions which accelerates the particles up to an energy of 7 MeV / u. An injection line (LEBT and MEBT) transports them to the synchrotron ring where they are injected, accelerated and extracted with an energy between 60 and 250 MeV for protons and 120 and 400 MeV/u for carbon ions. An extraction line (HEBT) guides the beam to the treatment rooms, where the patients are placed.



Two sources are installed in the existing LEBT. One is used to produce protons (O1) while the other for the production of carbon ions (O2). A third source (O3) will be installed in the LEBT CNAO with the aim of producing new ionic species both for clinical purposes (Helium, Oxygen) and for experimental purposes (Iron, Lithium).

2. Object

2.1. This document describes the specifications of n. 6+2 power supplies required to drive the steerer magnets of the Medium Energy Beam Transfer (MEBT) line, including a guarantee of 12 months from the date of acceptance.

2.2. The magnets to be driven are three, each with two windings, one for each plane; each winding will be driven independently by a dedicated power converter. The total number of power supplies required is therefore 6, plus two spare converters for a total of **8 units**. The power supplies will work in DC: they will receive a setpoint and maintain the corresponding current level for an arbitrary long time interval. Sometime they will be required to change value or to reach the maximum and the minimum current for resetting the hysteresis cycle of the magnet.

2.3. Table 1 summarizes the electrical characteristics of the load. The indicated resistance includes cables.

Table 1 – Electrical characteristics of the load

Magnet type	Resistance [mOhm]	Inductance [mH]
Steerers, single winding (H = V)	180	9.73

3. Functional requirements

3.1. This section lists the functional requirements of the power supplies.

3.2. The power supplies shall be standard commercially available units. A limited number of customization are allowed, to be discussed with CNAO and approved by CNAO. No fully custom units are acceptable.

3.3. The power supplies shall be enclosed in a case compatible with the installation in a 19" rack. No ventilation grids are allowed on the side or on top and bottom faces of the case.

3.4. The input voltage shall be 400 V (±10%), three phase or 230 V (±10%) single phase. Voltage frequency is 50 Hz.

3.5. All the electrical connections (AC, output, external interlocks, external analog reference) shall be placed on the back panel.

3.6. Each power supply shall be equipped with a general switch that cuts the supply line, shutting down the unit completely.

3.7. The units shall be air cooled.

3.8. A STANDBY state shall be foreseen in which the control electronics is active, but the output stage is off.

3.9. A POWER ON state shall be foreseen in which the output stage is active.

3.10. A FAULT state shall be foreseen which is triggered when an alarm is activated. In FAULT mode, the control electronics is active, but the output stage is off. When the alarm(s) are reset by the user or by the control system, the units will enter the STANDBY state.

3.11. At least two inputs for external interlocks, compatible with a clean contact, shall be available to stop the operation of the power supplies within 100 ms. The inputs shall react to the contact changing state from closed to open.

3.12. The power supplies must have a LOCAL and a REMOTE working mode: the first will allow the unit to be controlled by means of a local panel and display plus keys or a touch panel; the second requires the unit to be able to receive commands / setpoints and send read-backs / status information over an Ethernet connection. The selection of the working mode shall be possible only from the local panel.

3.13. The slope of the ramp used to reach the setpoint shall be selectable by the user, both in LOCAL and in REMOTE mode. The range of allowed ramp speed values shall be such that the full output current excursion, from –Imax to +Imax, will be completed between 1 second and 1 minute.

3.14. The power supplies shall typically operate in current mode. The possibility of working in voltage mode for testing purposes is also required.

3.15. Parameters of the control loop:

3.15.1. The parameters to tune the control loop (both the voltage loop the current loop) shall be accessible by the user, who will calibrate them in the field after the installation of the magnet and the cabling.

3.15.2. As an alternative, the loop can be calibrated at the factory for the specific load and may require some fine-tuning, for example to account for the real cable length, after the installation is complete.

3.15.3. In both cases there must exists a set of parameters that guarantees that no overshoot is present at the end of the ramp for the fastest allowed ramp speed.

3.15.4. In case of replacement of one power supply with a spare one, the settings shall be applicable by CNAO with no intervention by the Supplier, either by hand or from a file.

3.16. The power supplies shall be auto-protected from overloads and short circuits. Furthermore, it shall withstand with no damages the energy returning from the inductive load in case of sudden interruption of the supply voltage.

3.17. The power supplies shall continuously monitor the earth leakage current and switch into a fault condition when an adjustable threshold is reached.

3.18. The power supplies shall operate with an ambient temperature between 0°C and 40°C and a relative humidity between 30% and 80%.

3.19. The Supplier will commit to service the power supplies and make spare parts available for at least 15 years from the date of the delivery. In case components are discontinued, the Supplier commits to find compatible replacements or to modify the units to make them compatible with the new components.

3.20. After the installation and the final calibration carried out by CNAO, the performance of each type of power supply will be tested by CNAO according to a procedure and an instrumentation set that will be agreed between the Supplier and CNAO. In case the expected performance are not met, the Supplier shall make all the required modifications to match the performance indicated in this Specification within 2 months.

3.21. The supply will include:

3.21.1. The user manual in English (including the instructions for the maintenance);

3.21.2. The schematics of the power part;

3.21.3. All the software needed to setup the units and to configure them.

4. Performance requirements

4.1. Table 3 lists the performance requirements of the power supplies.

Table 3

Type of output current	Bipolar
Maximum output voltage	±15 V
Maximum output current	±60 A
Current setting and control range	-100% ÷ + 100% f.s.
Normal Operating Range (NOR)	-100% ÷ + 100% f.s.
Current setting and readout resolution	< ±2.0E-4 f.s.
Reproducibility	< ±1.0E-4 f.s.
Residual current ripple (pk-pk) within the NOR	< ±5.0E-5 f.s.
Accuracy	< ±5.0E-4 f.s.
Stability (8 hours)	< ±1.0E-4 f.s.

5. Non mandatory requirements

5.1. This section lists some requirements that are preferred, but not mandatory.

5.2. Virtual oscilloscope:

5.2.1. The power supplies should be equipped with a system that allows to capture the voltage and current waveforms at the output and to show them on a virtual oscilloscope interface, in order to tune the control loop parameters without the need of external instrumentation.

5.2.2. A minimum sampling frequency of 20 kHz is required.

5.2.3. The number of points per acquisition shall be such that a transient at least 5 second long can be acquired.

5.2.4. Some sort of trigger mechanism should be available to start the acquisition when a certain threshold value of the desired quantity is reached, as in an ordinary oscilloscope.

5.3. Arbitrary waveforms generation:

5.3.1. The power supplies should be equipped with an arbitrary waveform generation function.

5.3.2. The sampling frequency of the waveform should be at least 5 kHz.

5.3.3. The number of points that describe the waveform should be such that it can last up to at least 10 seconds.

5.3.4. It should be possible to load the points that describe the waveform into the power supplies through the Ethernet connection.

6. Deliveries

The supply of all power supplies must be completed within 9 weeks from the date of sending the purchase order.

Packaging and delivery of the power supplies to CNAO Foundation, located in Strada Campeggi n.53 – 27100 – Pavia, is responsibility of the supplier.