MAGNET POWER SUPPLIES FOR FERMI@ELETTRA*

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Abstract

FERMI@Elettra is the new 4th-generation light source, based on a single-pass FEL, under construction at the Elettra Laboratory in Trieste, Italy. Some hundreds of magnets and coils need to be supplied along the accelerator sections and the undulators chains - mostly individually - with currents as low as 5 A up to 750 A. Starting from a successful design developed at Elettra for the full-energy injector, a new version of the existing 4-quadrant, 5 A power supply (PS) has been studied. This new bipolar low-current PS, with full digital control, will be adopted for all 5 A loads. The design of a bipolar PS for supplying the 20 A loads is in progress, too. This paper will describe the proposed PS system for the magnets and coils of FERMI@Elettra. The focus will be on the solutions adopted to minimize the number of different PS types. Particular stress will be laid upon the in-house design.

INTRODUCTION

The FERMI@Elettra project is the construction of a new user facility for scientific investigations with high brilliance femtosecond pulses covering the wavelength range from 100 nm (VUV) to 3 nm (X-rays), located next to the third-generation synchrotron radiation facility ELETTRA in Trieste. The underlying technology of the new facility is the single-pass Free-Electron-Laser (FEL). Employing seeded harmonic cascade FEL schemes with APPLE II type undulators it will be possible to generate tuneable and controlled short-wavelength, high intensity photon pulses.

The new Booster-based full-energy injector [1] made the former injector of the ELETTRA Storage Ring available as fundamental part of the 1.8 GeV linear accelerator [2] for FERMI, supplied by a new electron source based on photoinjector technology [3].

LAYOUT OF THE FACILITY

A general layout of the facility (the underground part is located at a depth of about 5 meters, with an overall length of more than 350 meters) is shown in Fig. 1.

The accelerator and FEL complex (about 280 meters) comprises the following parts:

- the photoinjector and the main linear accelerator in which the beam is time-compressed and accelerated up to ~1.8 GeV;
- the system to transport the beam to the undulators (Transfer Line and Spreaders);
- the Diagnostic Beam Dump (DBD) – an alternative path for the electrons instead of being transported to the Undulator Hall for optics measurements on the beam itself;
- the undulator complex generating the FEL radiation;
- the Main Beam Dump (MBD) for the electrons at the end of the FELs.

The photon Beamlines from the FELs pass through the shielding wall and enter the Experimental Hall located underground (on the right in Fig. 1), too.

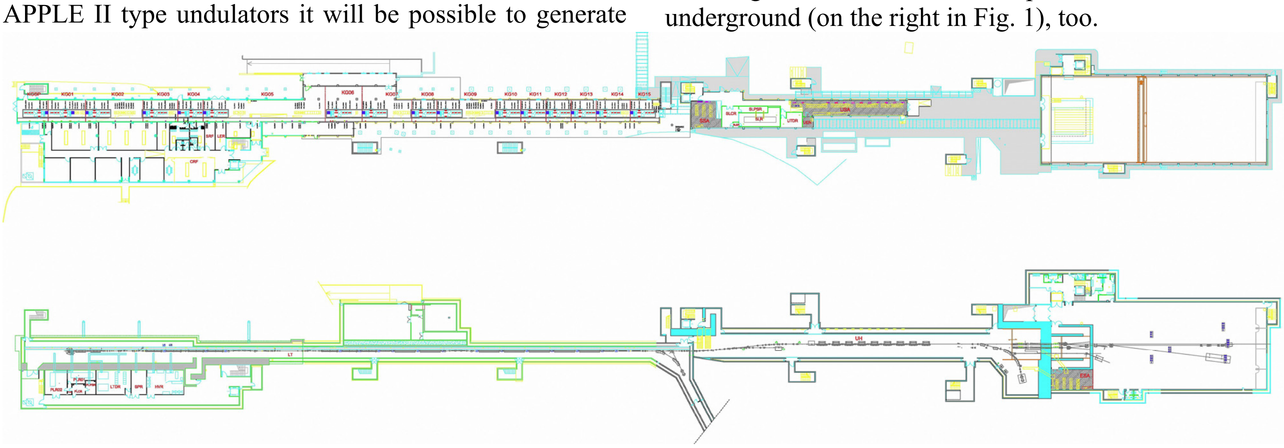

Figure 1: FERMI@Elettra general layout – the upper image shows the above ground structure, the bottom one is the underground complex (the Experimental Hall is located on the far right).

There are dedicated buildings above ground housing the "Service Galleries" where the cabinets and racks for the ancillary systems (RF plants, magnet power supplies, vacuum, instrumentation, control, protection, etc.) are located.

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MAGNETS AND DC POWER SUPPLIES

Almost 400 magnets and coils are distributed from the gun of the photoinjector to the end of the MBD. Almost all of them – with few exceptions (namely the dipoles in the bunch compression, spreader and beam dump sections) – are individually powered. A consistent number of magnets – the dipoles, quadrupoles and some correctors of the DBD and MDB – will be recycled from the not anymore used Linac to Storage Ring transfer line. Due to the different arrangements of the “old” magnets, the available space in the service galleries and to reduce the power consumption improving the efficiency, it was decided to install new power supplies (PS) only, without reusing any of the old ones.

For what concerns the new magnets, in order to minimize the number of different types of DC power supplies – simplifying the spare parts management and maintenance operations – a big effort in their design was dedicated in defining some “maximum excitation current categories” i.e. keeping the same maximum excitation current for as many types as possible by acting on the magnets’ geometry and size.

The following tables and figures summarize the number of magnets and the associated power supplies types in the relevant parts of the facility.

Gun and Linac

Distributed along the accelerating structure (165 meters), there are focussing coils mounted on the Gun and on the accelerating sections requiring some hundreds amperes and much smaller correction coils requiring a maximum of 5 A from bipolar power supplies; there are three magnetic chicanes – each of them with dipole magnets connected in series; there are three spectrometer lines for electron beam diagnostics. In addition, several quadrupoles and correctors are needed in the chicanes and in between the accelerating sections.

With the exception of the quadrupoles on the spectrometers, all quadrupoles (3 different types), correction coils and steering magnets (8 different types in air or on iron) are supplied by only 2 types of power supplies: ±5 A and ±20 A (bipolar, for uniformity).

Figure 2 shows the Linac layout and Table 1 summarizes the power supplies needed by the above mentioned coils and magnets.

Table 1: Power Supplies for Gun and Linac magnets

PS output [V/A]	# PS	Magnet
15/400	4	Gun Solenoids
15/100	6	Dipoles, Quadrupoles
100/100	2	Acc. Sections Solenoids
35/350	2	Dipoles Bunch Compressor
15/500	1	Dipole high energy Spectrom.
±10/±5	87	Quadrupoles, correctors
±15/±20	42	Quadrupoles, correctors

In total there are more than 20 different types of coils and magnets supplied by only 7 different types of DC power supplies.

Additional small PS, called “de-gaussing PS”, are needed on the dipoles of the spectrometers (when not in use) in order to null the remnant field in the magnets avoiding any interference on the electron beam.

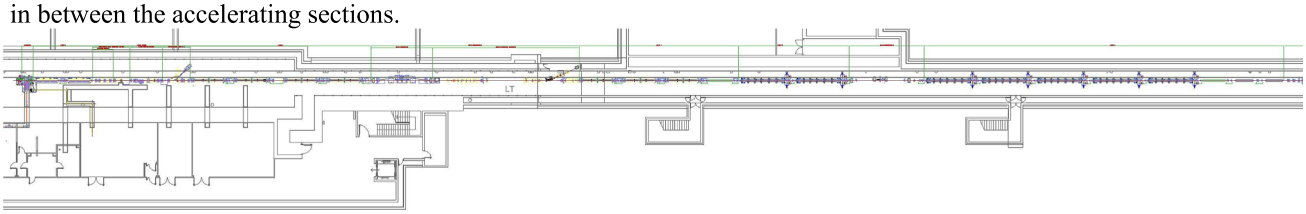

Figure 2: Gun & Linac layout with accelerating sections, spectrometers and electron bunch compressors

Transfer Line, DBD and Spreader

At the end of the Linac, a transfer line (TL) brings the electrons out of the Linac tunnel, through a shielding wall, to the adjacent Undulator Hall where the electrons are channelled either to the FEL-1 chain of undulators or the FEL-2 one (the so-called spreader section). In the middle of the Transfer Line, the DBD branches along the former Linac to Storage Ring Transfer Line tunnel.

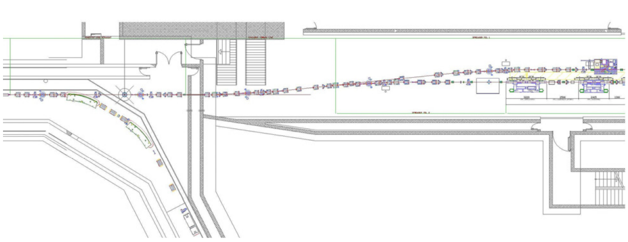

Figure 3: Layout of Transfer Line, DBD and Spreader

Figure 3 shows the layout while Table 2 reports the power supplies needed by the dipole, quadrupole and corrector magnets.

Table 2: Power Supplies for TL, DBD and Spreader

PS output [V/A]	# PS	Magnet
55/750	1	Dipoles DBD
35/125	5	Quadrupoles DBD
25/500	2	Dipoles Spreader
±15/±20	63	Quadrupole and correctors

A small de-gaussing power supply is needed also on one of the two spreader dipole power supplies.

FELs and MBD

Quadrupole and correctors magnets in between the Undulators and correction coils mounted on the Undulator themselves are needed along the two FEL structures. The MBD – needed to deflect and dump the electron preventing them from entering the Experimental Hall – makes large use of the "old" magnets (Fig. 4).

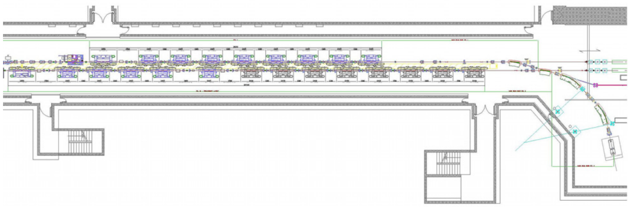

Figure 4: Layout of FELs and MBD

The power supplies associated to these magnets are listed in the following Table 3.

Table 3: Power Supplies FELs and MBD magnets

PS output [V/A]	# PS	Magnet
35/350	4	Dispersive Regions dipoles
25/750	2	Small MBD dipoles
55/750	1	Large MBD dipoles
35/125	4	MBD quadrupoles
±10/±5	126	Corrector magnets & coils
±15/±20	46	Quadrupoles and correctors

In this case 13 different types of magnets are supplied by 6 different types of power supplies.

ELETTRA IN-HOUSE DESIGN

In order to supply very low-power loads (1.5 A and 5 A) in the Booster based full energy injector of Elettra [4], a mixed digital-analog single-board power supply was developed at Elettra. The good performances and reliability of this design [5] [6] along with the large number of 5 A loads (about 200 magnets), encouraged the design of a new version of this type of power supply, equipped with a complete digital control [7]. The main parameters for the design are reported in Table 4 while Fig. 5 shows a prototype unit.

Table 4: Requirements for the 5 A power supplies

Parameter	Value
Output current range	± 5A
Output voltage range	± 10V
Nominal output power	50W
Short term stability	± 30ppm (± 150μA)
Long term stability	± 50ppm (± 250μA)
Switching Frequency	104kHz (TSW=9.6μs)

Four individual channels can be hosted in a standard 19", 3 HE sub-rack, along with the AC/DC auxiliary power supplies for the bulk power and control. Figure 6 shows a prototype sub-rack under test in the laboratory (two channels are mounted and connected to remote control via Ethernet).

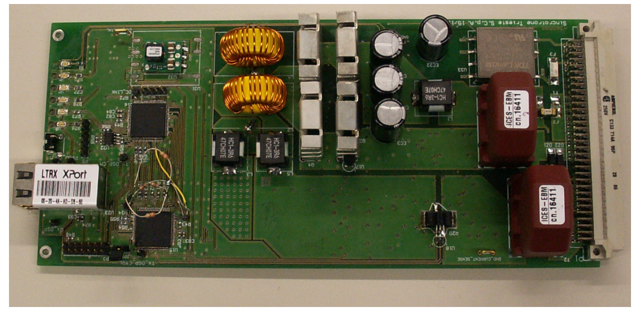

Figure 5: Prototype of the single-Board, 10 V/ 5A bipolar fully digitally controlled power supply designed at Elettra

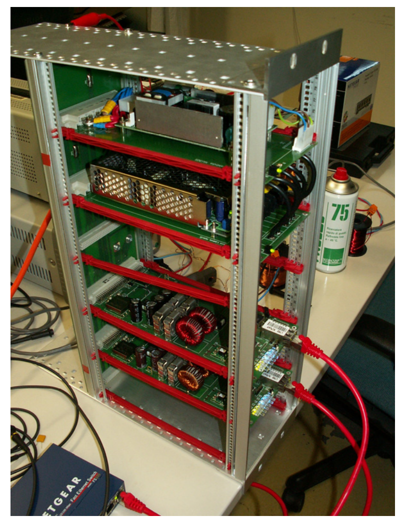

Figure 6: Prototype setup of a 4 channels sub-rack (two channels only are mounted and connected to the control)

A more powerful version, based on a two card layout (control and power), is currently in design. It will be used to supply the 20 A loads (>150 magnets in total).

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