MAGNET POWER CONVERTERS FOR THE NEW ELETTRA FULL ENERGY INJECTOR

Roberto Visintini, Giuseppe Cautero, Marco Cautero, Denis Molaro, Michele Svandrlik, Maurizio Zaccaria, Sincrotrone Trieste, Trieste, Italy.

Abstract

A large number of power converters has been required to supply the coils and the magnets of the four sub-structures of the new Elettra full energy injector. The Linac and the two transfer lines require highly stabilized DC power converters, while the Booster has to be operated at 3 Hz supplying the magnets with sinusoidal current waveforms. The extraction Bumper magnets require pulsed power converters. In order to keep all output voltages below 1 kV, a special connection has been adopted for the Booster dipoles. A particular type of low power four-quadrant converters with embedded Ethernet connection has been designed at Elettra for this specific project. The article will present the relevant facts about the different power converters and their performances.

INTRODUCTION

The structure of the new Elettra full energy injector comprises a Linac Pre-Injector (P), a low energy transfer line to the booster (PTB-TL), the Booster synchrotron (B) and a high energy transfer line to the Elettra Storage Ring (BTS-TL). Each sub-structure requires magnet power converters (MPC) with different characteristics in terms of output performances (see table 1).

Table 1: Magnet Power Converters – all Sub-Structures

Sub-Structure	Number of MPC	Type of output
Pre-Injector	32	DC – Uni- & Bipolar
PTB-TL	17	DC – Uni- & Bipolar
Booster	32	AC and pulsed
BTS-TL	31	DC – Uni- & Bipolar

SYSTEMS DESCRIPTION

A detailed description of the installed systems will be provided in the following sections.

Pre-Injector

The loads – focussing coils of the klystron, corrector coils and quadrupole triplets on the accelerating sections – are DC. The main parameters have been summarized in table 2.

The unipolar converters are standard products or – as in case of the klystrons' focussing coils ones – partially customized commercial products from the market. On the contrary, the bipolar ones have been designed at Elettra for the specific application [1]. This type of bipolar converters has been used also for the quadrupole triplets to increase the degrees of freedom in the optics.

Table 2: Magnet Power Converters – Pre-Injector

Magnet/coil	# of MPC	Output Ratings	Stability (>8 hrs)
Klystron Foc.	6	32 V / 215 A	$\pm 2\ 10^{-3}$
Buncher	1	45 V / 100 A	$\pm 5\ 10^{-4}$
Lens	5	170 V / 1.5 A	$\pm 5\ 10^{-4}$
Gun corr.	4	±12 V / ±1.5 A	$\pm 2\ 10^{-4}$
Triplets & corr.	16	±10 V / ±5 A	$\pm 2\ 10^{-4}$

Pre-Injector to Booster Transfer Line

The magnets are supplied in DC mode and – due to the electrons low energy (~100 MeV) – the converters ripple and stability figures are tight. Main parameters have been summarized in table 3.

Table 3: Magnet Power Converters – PTB-TL

Magnet	# of MPC	Output Ratings	Stability (>8 hrs)
Dipole	1	25 V / 200 A	$\pm 2.5\ 10^{-5}$
Quadrupole	8	10 V / 200 A	$\pm 2.5\ 10^{-5}$
Correctors	8	±50 V / ±20 A	$\pm 5\ 10^{-5}$

The dipole and quadrupole converters are almost standard products from the market while the corrector ones are a design from Diamond Light Source (DLS). The corrector converters use the digital control system designed by Paul Scherrer Institut (PSI) – see e.g. [2] – and adopted by DLS and Soleil ([3], [4]), too. The same power converters have been used also for the Booster correctors and the BTS-TL quadrupoles and – respectively – correctors.

Booster

The total inductance of the 28 dipoles connected in series and the peak current would have required either mid-voltage solutions (DLS [3]) or the splitting of the load in two parts (SOLEIL [4]) supplied by low-voltage power converters. The latter configuration has been also adopted for the Booster of Elettra, supplying separately the coils of the dipole magnets with two low-voltage/high current power converters. To avoid possible current mismatch among the magnets a special configuration has been adopted (Figure 1). Each dipole converter feeds 28 coils of separate magnets connected in series. There is a magnetic coupling through the yoke of the magnets between the loads that was taken into consideration in the design of the dipole converters.

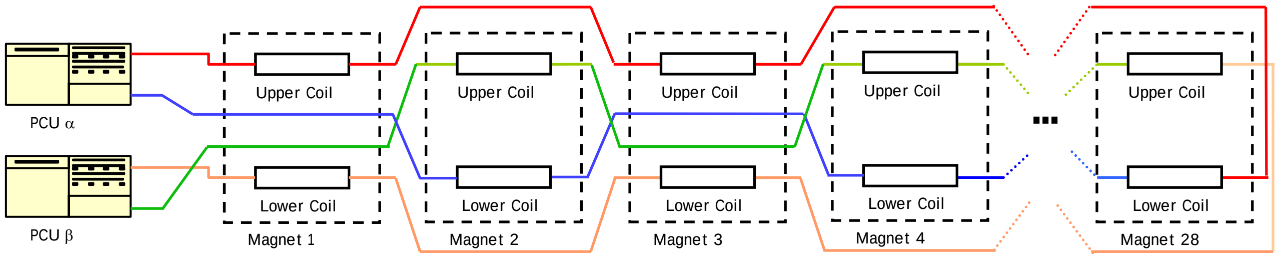

Figure 1: Dipole magnets connections (PCU – Power Converter Unit).

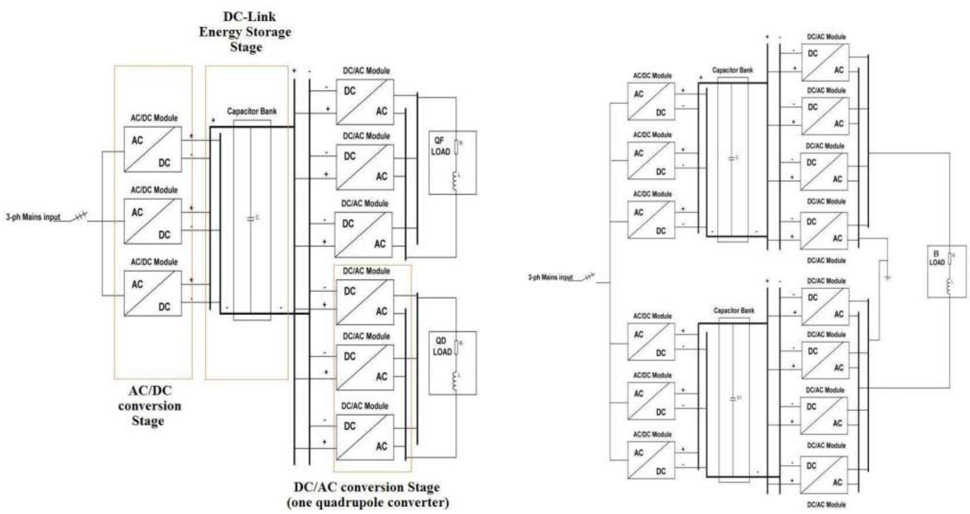

Figure 2: Structure of the Quadrupole (left) and Dipole (right) Power Converters.

A highly modular design has allowed the use of common units, along with the introduction of N+1 redundancy in every stage, both for the Dipole (two separate subsystems connected in series) and for the Quadrupole power converters (two separate, independent outputs that share the DC-Link and the AC/DC charging sections) as shown in Figure 2 [5].

Figure 3 shows the cabinets of the dipole converters.

Figure 3: Dipole Converters' Cabinets.

Figure 4 illustrates the quadrupole converters' cabinet whose doors have been opened to show the internal structure (refer also to Figure 2, left).

The output parameters of the booster converters are reported in Table 4.

Figure 4: Quadrupole Converters' Cabinet during the installation phase.

Table 4: Magnet Power Converters – Booster

Magnet	**# of MPC**	**Output Ratings**	**Stability (>8 hrs)**
Dipole	2	±1000 V / ±800 A	±5 10^{-5}
Quadrupole	2	±400 V / ±400 A	±5 10^{-5}
Sextupole	2	±70 V / ±70 A	±5 10^{-5}
Correctors	22	±50 V / ±20 A	±5 10^{-5}
Bumpers	4	120 V /13 A	±5 10^{-5}

All converters, besides the Bumper ones, adopt the already mentioned PSI digital control. Figure 5 shows the simulated output curves for one dipole converter. The measured current waveforms at the nominal frequency and peak current for both dipole converters are shown in Figure 6.

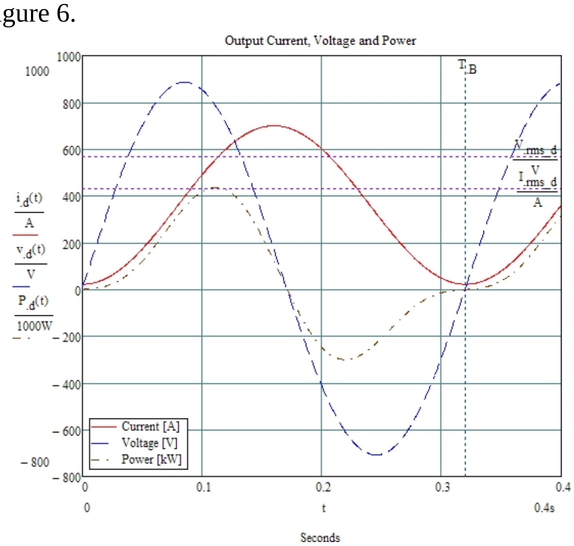

Figure 5: Example of output waveforms for each dipole power converter.

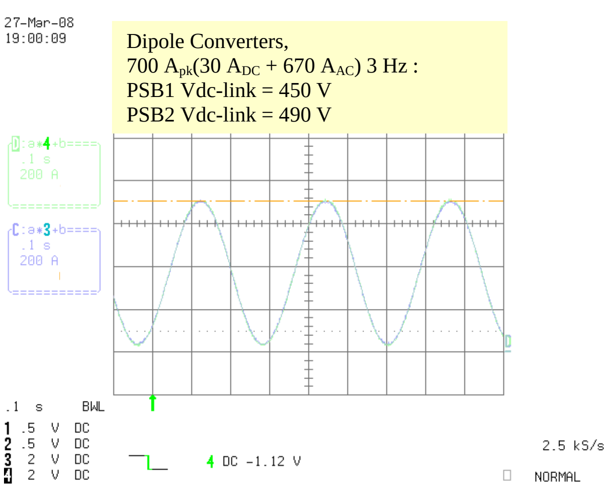

Figure 6: Measured current waveforms from the dipole converters at nominal frequency and peak current (the two traces are overlapped).

Unfortunately, there are still hardware and operational problems on the main converters that became evident only during the tests on the actual loads and are preventing the operations at full current and nominal frequency (3.125 Hz). Some progresses have been already done, as shown in Figure 6. A complete troubleshooting and refurbishing program is still ongoing. Elettra is now operating for Users, in agreement with the Booster Project time schedule, since March 3rd, 2008. The refurbishing process is therefore going on in parallel to the normal operation of the light source, with the obvious limitations on the availability of the power converters to carry out the refurbishing activities. The power converters are currently operated in a partial configuration to allow the refill of the Storage Ring.

The Bumper converters use standard market converters while the current feedback, waveform generation and interface to the Elettra control system are done using LabVIEW™ running on an industrial PC.

Booster to Storage Ring Transfer Line

Most of the magnets mounted on the BTS-TL have been recovered from the dismissed Linac to Storage Ring Transfer Line. The MPC – conversely – are new ones and their main parameters have been summarized in table 5.

Table 5: Magnet Power Converters – BTS-TL

Magnet	**# of MPC**	**Output Ratings**	**Stability (>8 hrs)**
Dipole “13”	1	105 V / 1000 A	±5 10^{-5}
Dipole “25”	1	35 V / 1000 A	±5 10^{-5}
Quadrupole	13	25 V / 100 A	±2.5 10^{-5}
Correctors	16	±50 V / ±20 A	±5 10^{-5}

CONCLUSIONS

More than 100 magnet power converters have been installed on the New Full Energy Injector of Elettra. Due to some hardware and operational problems, the main converters for the Booster have not yet achieved the required performances and a refurbishing process is ongoing during the normal operation of Elettra.

REFERENCES

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