ISBN: 978-3-95450-231-8 ISSN: 2673-5490 doi: 10.18429/JACoW-IPAC2023-WEPM076

ELETTRA 2.0: MAGNET POWER CONVERTERS STRATEGY

M. Cautero †, R. Visintini, E. Yousefi, M. Zaccaria
Elettra Sincrotrone Trieste, 34149 Basovizza, Italy

Abstract

Elettra 2.0 is the Project finalized to upgrade the Storage Ring (SR) and part of the beamlines (BLs) of Elettra. The machine optics requires a significant number of magnets and additional coils to energize individually. More than 1200 DC power converters (PCs) are foreseen. A synergic design of the magnets and the associated PCs led to a great standardization: four current ranges (300 A, 100 A, 25 A, 5 A) and, consequently only four different types of PCs. While the 20 V/300 A PCs (72 units) have been ordered on the market with a "built-to-specification" procedure, the 15 V/100 A and the 10 V/25 A units (together account to about 1000 units) are an in-house design and their procurement will follow a "built-to-print" procedure. The 15 V/5 A type (not less than 250 units) is still under design and will follow the same approach of the 100 A and 25 A ones. This paper gives an overview on the magnet power converter system, the results of the tests on the prototypes and the installation strategy.

ELETTRA 2.0 REQUIREMENTS

At Elettra, in 25 years of experience, water-cooling has been causing a non-negligible source of downtime when related with power electronics. Sometimes leaks are causing fatal damage to the cooled circuits. By contrast, air-cooling requires a stable air temperature and a constant flow to minimize effects on the stability of the output current from the power converters [1]. One solution to this problem is to enclose all the power electronics inside thermal stabilized racks. This reduces heat load to the Service Gallery and take advantage of the cooling water pipes already existing for the present cabinets of the power supplies.

The one-to-one correspondence (power converters – magnets) implies a large number of power cables to the SR. However, a kind of optimization could be placing the converters in the same positions of the present cabinets allowing re-using the existing cable trays.

Shortening the length of cables has the advantage of limiting the EMI introduced, therefore using shielded power cables might not be needed.

Design Phase

The power converters grid connection shall be split in two, normal AC mains for the power part and UPS (Uninterruptable Power Supply) for the control part. So for example, if a power outage occurs during a thunderstorm event and powers off some devices, the control part, fed by the UPS line, is still available at the control system, therefore some analysis can be performed, and to minimize the number of AC cables, we shall use custom made PDUs (Power Distribution Units for 3 and 1-phase) with required plugs. In close discussion during the designing phase with the Magnet [1], Control and Protection group the following optimization has been carried out:

2 types of dipoles use the same type of power converter

3 types of quadrupoles and 3 types of sextupoles require only one type of power converter

Embedded correctors, fast correctors and skew quadrupole use the same type of power converter

Unified control hardware (e.g. Ethernet interface with TCP-IP sharing the same set of commands), same interlock signals logic, and same driver software.

For the complete machine, magnets will be powered by just 3 kinds of power converters.

Table 1 summarizes the required parameters to the power converters.

Table 1: Power Converters Requirements

Magnet Type	Dipole	Sext	Quad	Skew-Quad	Corr	Oct	TrimC	Fast Corr	Unit
PS Mode	Unipolar			Bipolar		Unipolar	Bipolar	Bipolar	
PS Type	PSB	PSQS		PSC		PSOC	PSB_T	PSFC	
Max Iout	**300**	**100**		**20**		**100**	**100**	**5**	A
Max Vout	20	15	15	10	10	10	5	*TBD*	V
Max Pout	6	1.5	1.5	0.2	0.2	1.0	0.5	5*Vout	kW
Op. Range	5 – 95	5 – 95	5 – 95	Full	Full	5 – 95	Full	Full	% Iout
Stability (8h)	30	100	25	50	20	100	100	20	ppm_{pp}/FS
Ripple	30	100	100	100	500	100	100	500	ppm_{pp}/FS
Total PS	72	432		432		48	48	192	1224

† marco.cautero@elettra.eu

ISBN: 978-3-95450-231-8 ISSN: 2673-5490 doi: 10.18429/JACoW-IPAC2023-WEPM076

MAIN MAGNET POWER CONVERTERS

The main distinction among the different types of power converters is the type of load to supply.

Dipole Magnet Power Converters

The output current and voltage of the dipole power supplies are compatible with high-performance products available on the market and there are at least three possible manufacturers. The expected size of each power supply is standard 19", 3U high. At the time of writing the article, the call for tender relative to the power converters has been won by the RTI company OCEM-CaenELS proposing the NGPS power converter (300 A @ 30 V). This power converter fulfils all the technical specifications required in the call for tender and is shown in Fig. 1.

Figure 1: NGPS 300 A 30 V power converter.

Multipole Magnet Power Converters

Following past successful experiences [2-4], the multipoles power converters shall be an in-house development, counting about 75% of all power supplies.

The converters need to source at least 100 A with a maximum voltage of 15 V. The expected size is 2U high. The power part consists in hard-paralleling two power boards capable of sourcing/sinking 60 A each. The power mosfet are OptiMOS™-5 Power-Transistor from Infineon, showing GaN like specification. The power lines have been carefully designed to minimize the stray inductance and perform minimal routing. The boards are driven with a symmetrical feed-line of power and output lines symmetrical connections give us the perfect matching of the output current in each board as shown in Fig. 2.

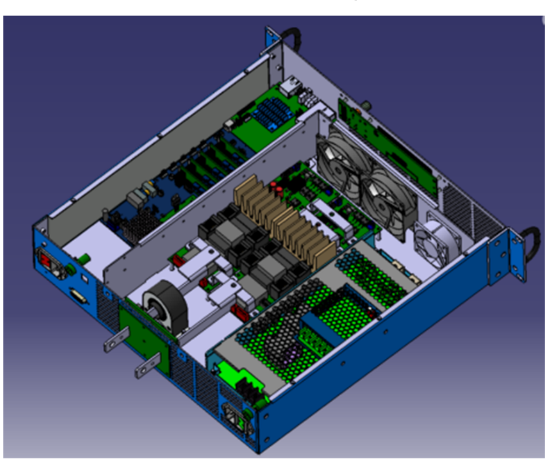


Figure 2: A38100, 4-Quadrant multipole power converter.

Current sensors are mounted in the input stage, to shut down the machine in case the unbalance of the input current for the boards gets to higher values than expected. The type is a 4-Quadrant power converter, if unipolar operation is strictly needed the remaining quadrants can be disabled by firmware means.

Our converters are on the prototyping phase, soon they will be validated and a built to print call for tender will be run.

CORRECTOR, SKEW QUADRUPOLE, AND FAST POWER CONVERTERS

These different magnets can be powered by one type of converter and shall be an "in-house" development as well. This type must be operating in 4-Quadrant, and a big effort has made possible the sharing of all the parts of the multipoles converter. The power board is just one instead of two used in the multipoles as shown in Fig. 3.

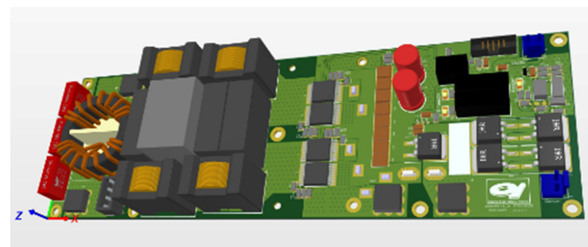


Figure 3: 60 A, 4-Quadrant power converter.

It uses a different DCCT and a smaller bulk DC-Link due to the lower power, but all the critical components like the control and the power are the same. This leads to enormous simplification on the maintenance and spare support, not to mention the simplification of the software infrastructure needed to interface all types of converters used. Expected size shall not exceed the standard 19", 1U high, as shown in the first prototype in Fig. 4.

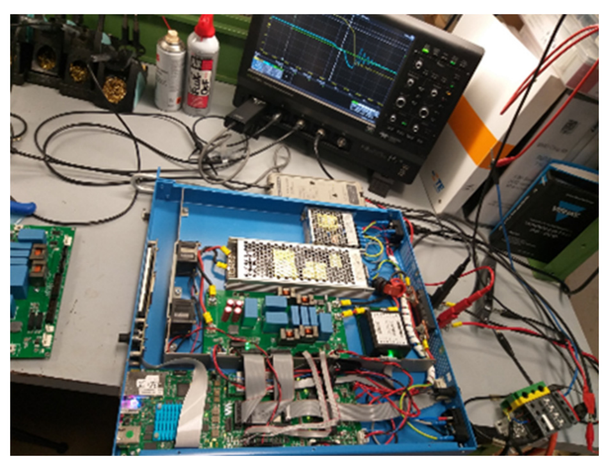
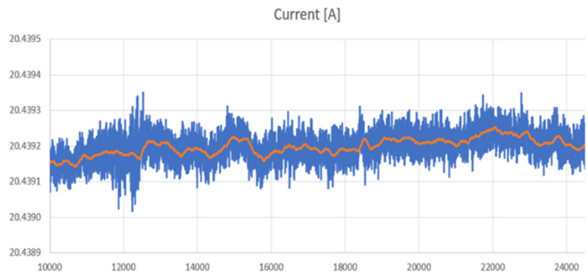


Figure 4: A3820, 4-Quadrant corrector power converter.

For what concerns the stability figures and the ripple analysis, the stability plot of 8 hours observation is shown in Fig. 5. A LEM Saturn Ultrastab and a Keithley 7 ½-digit digital multimeter were used for the measurement setup.

ISBN: 978-3-95450-231-8 ISSN: 2673-5490 doi: 10.18429/JACoW-IPAC2023-WEPM076

DCCT1				
Setp	Imax	Imin	Delta-pp[PPM]	Moving Average
20	20.43935	20.43902	16.65	5.54



Temperature ['C]		
tmax	Tmin	Delta
19.46189	19.23142	0.23047

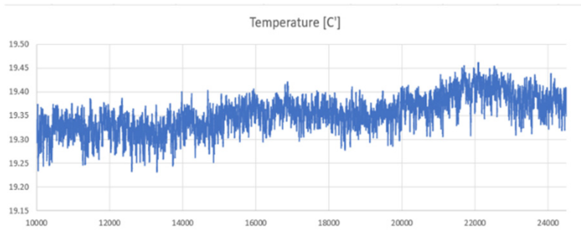


Figure 5: 8-hour stability test.

The required specifications in terms of noise and ripple are reported in Table 1. It can be seen that the 50 ppm/FS limit requirement is fully met, showing an outstanding moving average (16 points) of 6 ppm/FS stability over the observation time in an uncontrolled temperature environment. The output current ripple measurement is shown in Fig. 6. The residual noise in a 200 kHz bandwidth measurement with a LeCroy CP030A current probe is 8 mA_{pp} meaning 400 ppm/FS, within the specifications.

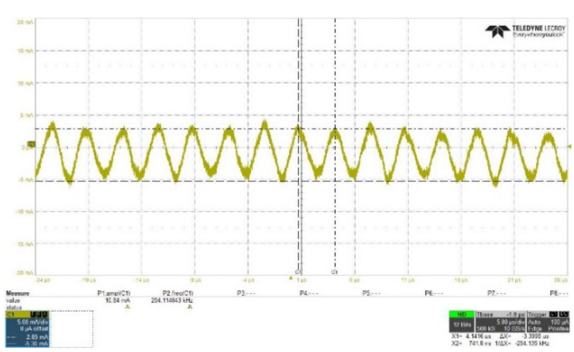


Figure 6: A3820 Ripple test @ 10A.

STATUS OF PROCUREMENT

The call for tender for the 76 converters for the dipole magnets has been already closed and assigned to OCEM-CaenELS for the delivery of the NGPS type power supply.

The delivery to Elettra of the power converters is made in batches and shall begin in June 2024, while the last unit shall be shipped in June 2025. In July 2026 the site acceptance tests will be over, letting the commissioning of Elettra 2.0 start-up.

The built to print call for tender for the multipoles and the corrector type power supply will be open on the fourth trimester of 2023, specifications and documentation now being redacted.

CONCLUSION

We have reported the status of the design and procurement of the magnet power converters for Elettra 2.0. The unipolar converters for the dipole magnets are a standard off the shelf product and have been deeply factory-tested.

The in-house design of the multipoles and corrector converters, shall be manufactured by an external company (and tested by us on a pre-series), but some prototypes are already running at Elettra for burn-in tests.

REFERENCES

[1] D. Castronovo, A Gubertini, D. Rainone, D. Caiazza, E. Karantzoulis, and I. Cudin, “The new Elettra 2.0 magnets”, presented at IPAC’23, Venice, Italy, May 2023, paper MOPA140, this conference

[2] R. Visintini and M. Cautero, “A 20-Ampere, 4-quadrant power supply for magnets”, in *2nd IEEE Southern Power Electronics Conference (SPEC’16)*, Auckland, NZ, December 2016, paper 115, `doi:10.1109/SPEC.2016.7846023`

[3] R. Visintini, M. Cautero, T. N. Gucin, and C. A. Martins, “Power Converters for the ESS Warm Magnets: Procurement Status”, in *Proc. IPAC'19*, Melbourne, Australia, May 2019, pp. 1251-1254. `doi:10.18429/JACoW-IPAC2019-TUPMP012`

[4] R. Visintini, M. Cautero, G. Göransson, C. A. Martins, and P. J. Torri, “Power Converters for the ESS Warm Magnets”, in *Proc. IPAC'17*, Copenhagen, Denmark, May 2017, pp. 3372-3374. `doi:10.18429/JACoW-IPAC2017-WEPVA051`