THE NEW ELETTRA BOOSTER INJECTOR

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Abstract

The new full energy injector for Elettra is under construction. The complex is made of a 100 MeV linac and a 2.5 GeV synchrotron, at 3 Hz repetition rate. With the new injector top-up operation shall be feasible. In the first semester of 2007 the machine assembly has been started. Start of the commissioning is scheduled in Summer 2007, while the connection to the Storage Ring is planned in Fall. This paper reports the project status.

GENERAL STATUS AND SCHEDULE

Installation of the full energy booster injector for Elettra [1] is going on. The new building hosting the accelerator complex, located in the centre of the existing storage ring building, is completed. Plants installation is fairly advanced; they will be running by July.

Almost all accelerator components have been delivered. Magnets have been produced by Danfysik and Tesla Engineering [2]. Dipole magnets are already positioned in the booster, as well as one third of the girders. Figure 1 shows a girder with vertical steerer (total 10 horizontal, 12 vertical), defocusing quadrupole (18 QD, 18 QF), sextupole (12 SD, 12 SF). Beam Position Monitors (total 22) are located between quadrupole and sextupole.

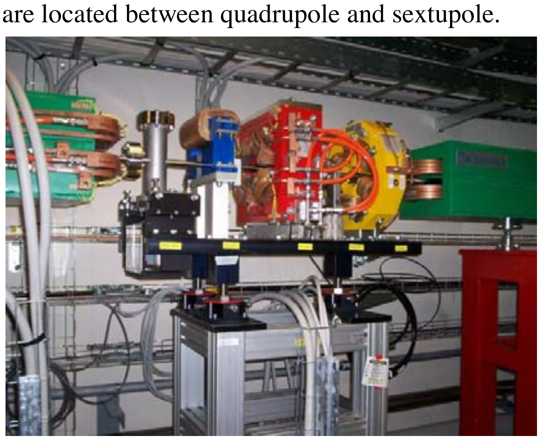

Figure 1: Girder installed on the booster.

The vacuum chambers have been built by RIAL (Italy). Before installation they have been pre-assembled with the girder magnets and with the dipoles. Once girders and dipoles are positioned and pre-aligned, flanges between them are connected. Each girder is equipped with an ion pump and pressure measuring gauges.

Power converters for dipole, quadrupole and sextupole magnets have been constructed by Kempower OY (Finland). Factory acceptance tests were performed beginning of June and delivery is ongoing.

The radiofrequency (RF) power plant is taken from the storage ring after its upgrade with a new system [3].

Commissioning of the pre-injector shall start in August 2007. Booster commissioning will follow until the end of September. Goal of this first commissioning period is to demonstrate the correct functionality of all systems and to extract beam from the booster at 2.5 GeV. From October to December Elettra will be shut-down to allow connection between booster and storage ring. High energy transfer line commissioning is then planned in January 2008, while in February user’s operation shall start again. In parallel, tests dedicated to the *Top-Up* operation mode will be performed during the first semester of 2008.

PRE-INJECTOR LINAC

The new 100 MeV pre-injector linac has to provide single and multibunch operating modes. Figure 2 shows the layout and table 1 summarizes the beam parameters.

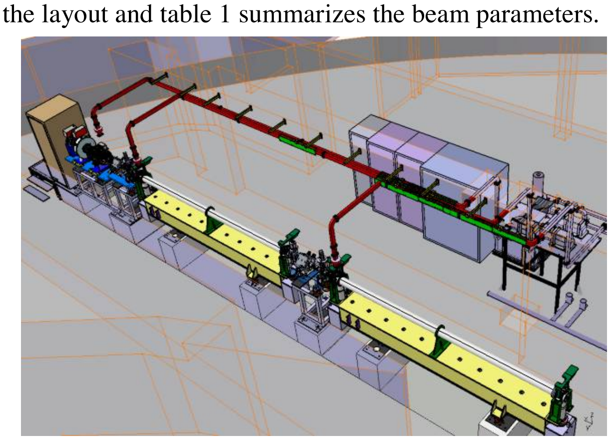

Figure 2: Pre-Injector layout

Table 1: Pre-Injector main beam parameters

Parameter	**Single Bunch**	**Multi Bunch**
Nominal beam energy	100 MeV	
Pulse width	≤ 2 ns	10-100 ns
Beam current (at 100 nsec)	≥ 20 mA	
Charge/pulse	≥ 0.15 nC	≥ 2.0 nC
Pulse repetition rate	1-10 (nominal 3) Hz	
Emittance (at 100 MeV)	≤ 1.0 mm mrad	
Energy spread	≤ 0.5 %	
Storage Ring filling time	5 min	

The machine is composed of a gun, a bunching section and two LIL accelerating sections, donated by CERN. The electron source is a conventional thermoionic gun using a planar triode (TH 306) that will be operated up to 85 KeV. The bunching section is composed of a 500 MHz pre-buncher, a pill-box cavity operating in the TM_{010} mode, with up to 50 KV gap voltage, and a 3 GHz buncher made of a graded bi-periodic standing wave structure, 0.6 m long, operated in the $\pi/2$ mode. The average energy gain in the buncher will be 6.6 MeV with 1.3 MW RF input power and the two 4.5 m LIL sections will rise the beam energy to the specified value, 100 MeV.

The RF power for the whole 3 GHz system will be supplied by a 45 MW klystron (Thales TH2132A). We will install a second RF power station, with a waveguide switching system that allows the second klystron to operate on waveguide loads, to have a spare tube always available in case of fault or replacement of the main one.

FAST MAGNETS

Injection and extraction processes are performed by the combined action of septum and kicker magnets. For extraction there are also four bumper magnets. Booster septum magnets are derived from those of the Elettra storage ring injection ones; as such they are driven by capacitive discharge-like circuits, the current pulse being about a 50 μs half-sine wave. The shielding action is given by a suitable copper screen (eddy current or passive septum).

Booster kicker magnets are driven by square current pulses produced by the basic circuit shown in figure 3, where **L1** is the total inductance seen by the generator, **T1** is the Pulse Forming Network (PFN) and **C1** is a suitable speed-up capacitor. The thyratron cathode-grounded configuration is used, a proven technology related to biasing the tube itself.

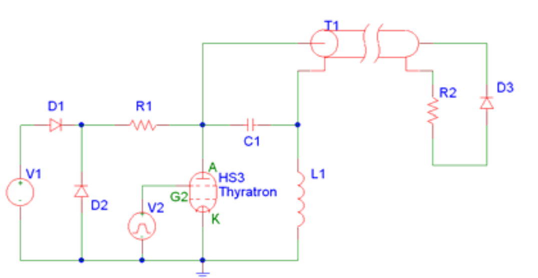

Figure 3: Pulse generator schematic.

The injection kicker is a window frame ferrite core module; it is realized assembling four CMD 5005 ferrite blocks, machined and provided by Ceramic Magnetics, packed and housed in a suitable stainless steel box as can be seen in figure 4.

The extraction kicker is made by two such modules connected in parallel to the pulse generator. In this case the parallel connection has been chosen in order to keep the total inductance seen by the generator low. During laboratory tests some optimization sessions were needed to adjust the speed-up capacitor value. The final extraction kicker current pulse is shown in figure 5.

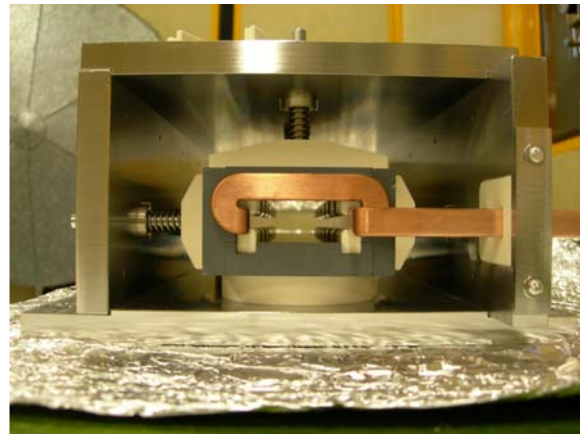

Figure 4: Kicker module.

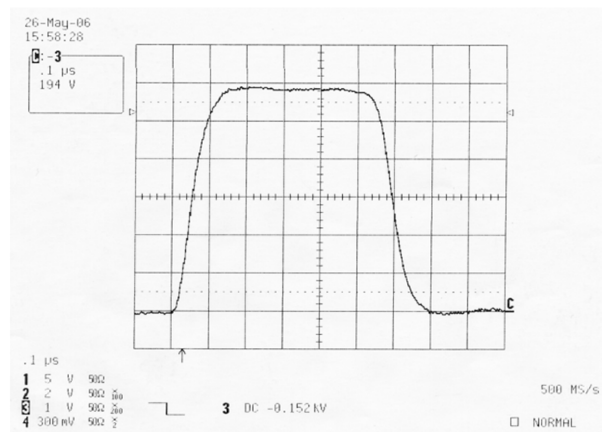

Figure 5: Kicker current pulse (Vert. scale: 194 A/div, Vcharge = 30 kV, Ltot ~ 1 μH, C1 = 482 pF)

POWER CONVERTER UNITS

There are 28 separate Power Converter Units (PCUs) for supplying the magnets. Table 2 summarizes their output parameters while figure 6 shows the output waveform of the dipole PCUs – those of the quadrupoles are similar but with lower amplitude, while the sextupole and corrector power converters must be able to follow quasi-arbitrary periodic waveforms. In table 2 type means: 2Q = 2 Quadrant, bipolar in voltage and unipolar in current; 4Q = 4 Quadrant, bipolar also in current.

Table 2: Booster magnet Power Converters

	I_{out} [A]	V_{out} [V]	# Units	Type
Dipole	15 - 800	+/- 1000	2	2Q
Quadrupole	5 - 400	+/- 400	2	2Q
Sextupole	+/- 70	+/- 70	2	4Q
Corrector	+/- 20	+/- 20	22	4Q

The PCUs use Pulse Width Modulation (PWM) techniques and supply the magnet strings directly, without White Circuit, as it was first done for the Swiss Light Source. The Digital Control, also developed at PSI, has become a *de facto* standard, widely used by other particle accelerators. This control has been adopted by Elettra,

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too [4]. The combined use of digital control and PWM techniques to directly supply the magnets has been proven very reliable [5]. Its adoption for the booster of Elettra will let more freedom in choosing the cycling frequency of the booster and the waveform of the excitation current in the magnets. It will also facilitate the implementation of the "stop-and-go" operations required by top-up.

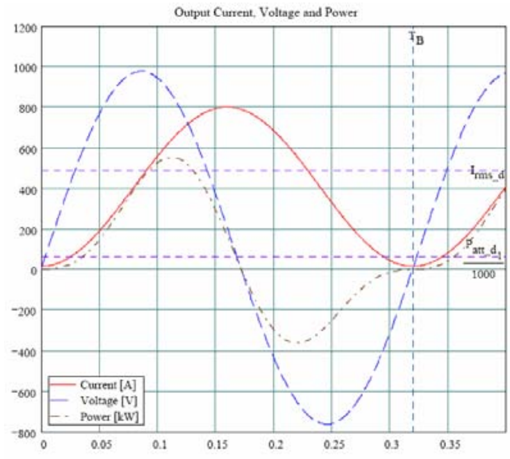

Figure 6: Dipole PCUs output waveforms

Being all PCUs operated synchronously, one of the main issues of their design is the reduction of the impact on the mains, both minimizing the induced harmonics and keeping the power absorption as constant as possible. This has led to a design including large DC-Link capacitor banks for effective energy storage when the energy is recovered from the magnets.

High reliability and ease of maintenance are also key features. A total modular design is adopted allowing the introduction of N+1 redundancy in all "sections" and the use of the same "building blocks" for the dipole and quadrupole PCUs. Figure 7 shows the structure of the quadrupole PCUs that share the same charging and energy storage sections with two separate outputs in one cabinet.

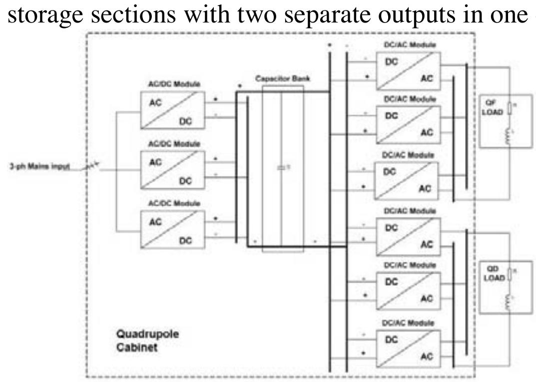

Figure 7: Quadrupole PCUs structure – the same subunits are also used for the dipole PCUs.

CONTROL SYSTEM

The control system [6] consists of several VME based computers distributed around the machine that interface with the different equipment. The control system architecture is shown in figure 8. A number of PC-based consoles allows to remotely operate the machine from the control room, while a switched Ethernet network connects all the control system computers. A uniform and homogeneous software environment using the GNU/Linux operating system and the Tango toolkit has been adopted for the whole control system. A high level software framework supports model based design of machine physics applications. General purpose control room applications (graphical panels, synoptic, alarms, archiving, logging, etc.) are implemented using the Tango tools.

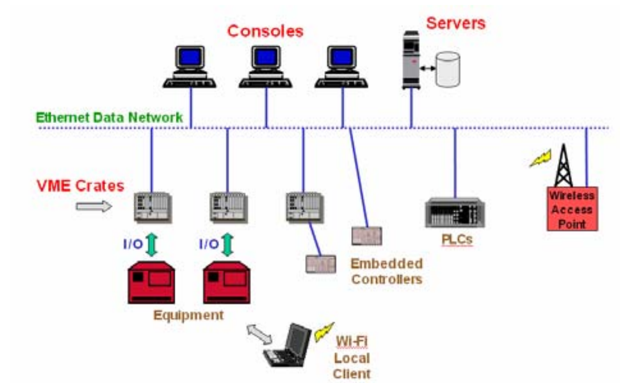

Figure 8: Control system architecture.

The equipment protection and access control systems adopt a centralized architecture with Siemens S7 Programmable Logic Controllers (PLC) and a number of distributed I/O peripherals connected via Profibus. The PLCs communicate with the control system through Ethernet TCP/IP interfaces. Given the extremely high degree of safety required, fail-safe versions of PLC, Profibus and I/O peripherals are adopted for the access control system. Special care has been taken in the design in order to protect beamline personnel during top-up injection, performed with open beamline stoppers.

All of the hardware components have been delivered and are being gradually installed in the machine, while the equipment to control the pre-injector has already been deployed. Software development is underway and most of the Tango devices and graphical panels to control the pre-injector are already operating.

REFERENCES

[1] M.Svandrlik et al., "Elettra New Full Energy Injector Status Report", Proceedings of EPAC 2006, Edinburgh, Scotland.
[2] D.Zangrando et al., "The Elettra Booster Magnets", this conference.
[3] A.Fabris et al., "RF System for the Elettra New Full Energy Booster Injector", this conference.
[4] R.Visintini, D.Molaro, P.Korhonen, "Power Converters for the Magnets of the New Elettra Booster Synchrotron", PCIM2007.
[5] F.Jenni, R.Kuenzi, A.Luedeke, L.Tanner, "Five years of operational experience with digitally controlled Power Supplies for beam control at PSI", EPE2005.
[6] M. Lonza et al., "The Control System of the Elettra Booster Injector", ICALEPCS'05.

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