

## THE PERSONNEL SAFETY SYSTEM OF THE ELETTRA BOOSTER

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### Abstract

The new injector of the Elettra storage ring is based on a 100 MeV linac feeding a 3.125 Hz booster synchrotron. The booster is designed to accelerate the electron beam up to the maximum energy of 2.5 GeV, providing full energy injection into the storage ring.

The Personnel Safety System (PSS) of the new injector protects personnel from radiation hazards by controlling access to restricted areas and interrupting the machine operation in case unsafe conditions occur. The system is based on Programmable Logic Controller (PLC) technology providing redundant logic in a fail-safe configuration.

This paper describes the radiation safety criteria that have been defined to minimize radiation exposure hazards as well as the technology and architecture chosen for the PSS implementation.

### INTRODUCTION

The new injector has been designed to replace the pre-existing 1.2 GeV Linac and allow for full energy injection into the 260 m long storage ring. The final goal is to operate Elettra in top-up mode, i.e. keeping the stored current almost constant through frequent injections without closing the beamlines safety shutters.

The new injector consists of a 100 MeV linac ("Preinjector"), a first transfer line from the preinjector to the booster ("PTB\_TL"), a 3.125 Hz booster synchrotron ("Booster") and a second transfer line from the booster to the storage ring ("BTS\_TL").

The commissioning has been divided into different phases [1].

It started in September 2007 and, up to December 2007, the injector parameters have been optimized operating the machine in local mode. The existing 1.2 GeV linac was used to refill the storage ring until October 8<sup>th</sup>, 2007. From January on, the injector has been connected to the ring and the second phase of the commissioning has started.

The PSS implemented in the first phase has been modified to be interfaced with the ring PSS. The main criteria on which it is based are fail-safe and redundancy (double door switches, double and different switches for each beam stopper, etc.)

At present the PSS controls:

- A) five different areas (Figure 1), separated from each other by interlocked doors:
- the injector tunnel (yellow)
  - the right side area (green)
  - the left side area (blue)
  - the booster internal area (pink)
  - the booster roof (violet).

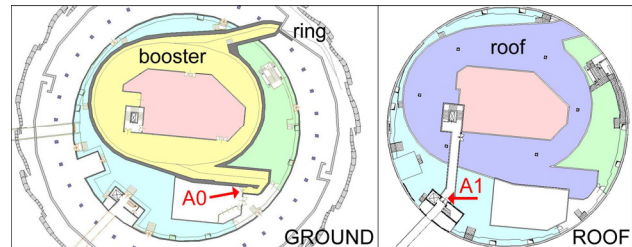


Figure 1: Booster areas (ground level and roof) with the two access doors (A0 and A1).

- B) four beam stoppers (Figure 2), placed one in the booster section n.14 (called BST\_BTS14.1) and the others along the booster to storage ring transfer line (BST\_BTS1.1, BST\_BTS1.2 and BST\_BTS1.3)

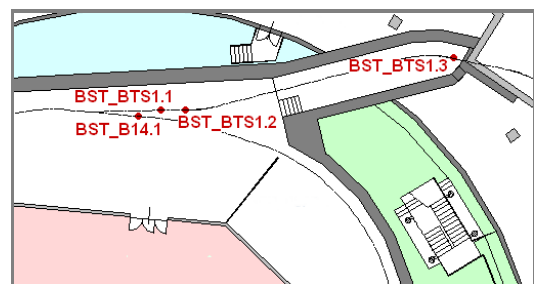


Figure 2: Beam stoppers controlled by the PSS.

- C) the electron gun  
 D) the RF power both of the preinjector and of the booster  
 E) the radiation monitors placed both in the Preinjector Service Area and in the Experimental Hall.

### MODES OF OPERATION

A system based on three beam-mode keys (the 3<sup>rd</sup> key is not yet operative because top-up modality has not been implemented, yet) allows to define five modes of operation for the new injector:

1. Booster RF-Service
2. Booster Shutdown
3. Booster OFF
4. Booster On Loc
5. Booster On Injection

In the "Booster RF-Service" mode, the PSS permits to operate the booster RF cavity keeping free the access to the tunnel. The cavity front side, facing the corridor where people can pass, is shielded by lead, while the cavity back side is fenced to keep personnel off.

In the "Booster Shutdown" mode, the PSS inhibits all the operations with the preinjector and the booster and access into the tunnel is free. If the beam is stored inside

the storage ring, the PSS inhibits opening the third beam stopper of the BTS\_TL (BST\_BTS1.3): hence scattering radiation cannot channel from the ring to the booster through the vacuum chamber and safety conditions are assured for the personnel working inside the booster tunnel.

When the Booster is “OFF”, access is “controlled” and personnel can enter the booster tunnel following the procedure described in the following chapter. In this mode operators can execute the tunnel search. At the end of the operation, if also the external areas have been searched, the PSS permits to open the beam stopper BST\_B14.1 and, after a delay during which an acoustic alarm sounds, operations with the beam can start.

The “Booster On Loc” mode allows to operate the injector locally, without injecting the beam into the storage ring. In this mode the three beam stoppers placed along the booster to storage ring transfer line are closed and, if the storage ring inhibits injection (e.g. because somebody is present inside the ring tunnel), also locked. Access inside the injector tunnel is forbidden.

The “Booster On Injection” mode is reached if at least one of the three above mentioned beam stoppers is open. This mode permits to inject into the storage ring with all the beamlines safety shutters closed. Access inside the injector tunnel is forbidden. The beamlines radiation monitors interrupt the injection if a predefined radiation dose threshold is exceeded.

## ACCESS CONTROL CRITERIA

The injector tunnel has two entrance doors, which also work as emergency exits.

The procedure to enter the tunnel provides the supervision of an operator from the control room who gives the final assent by unlocking the door.

To permit the access, the control room operator must dump the beam and reach the “Booster OFF” mode by switching off the gun, the RF power both of the preinjector and of the booster and by closing the booster beam stopper BST\_B14.1, in order to be sure that no beam is stored in the booster.

Once these conditions have all been fulfilled, the person who wants to enter must:

- pass his magnetic badge in the badge reader placed next to the access door (Figure 3)
- extract the safety key which is unlocked by the PSS once the badge is recognized as authorized to the access (there are 8 safety keys for each door)
- wait for the final assent given by the control room operator, who unlocks the door after recognizing the person through a video camera
- open the door, enter, close the door and deposit the safety key in the internal key-panel

As long as a safety key is absent from the external panel or a name is registered in the PLC list, the PSS prevents the control room operator from switching on the gun and the RF.

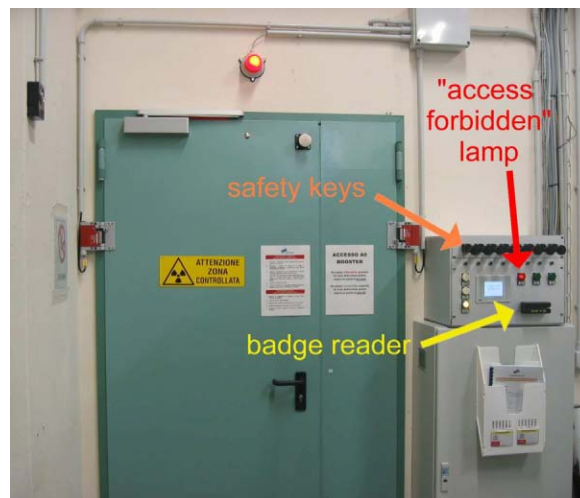


Figure 3: The badge reader and the safety key panel next to A0 door.

A time-out is provided for each step of the procedure described above: if the available time expires, an anomaly status is generated, which can be reset only by the control room operator by pressing the “Reset” button in the PSS interface.

To get out of the tunnel, one must extract a safety key from the internal panel, unlock the door by pressing the “unlock” button, open the door and exit, close the door, insert the safety key in the external panel and pass the magnetic badge in the reader.

Two LCD displays placed next to the safety key panel both inside and outside the tunnel help the person in the entrance/exit procedure suggesting what to do next.

## SEARCH PROCEDURE

The tunnel search requires the presence of two operators, one executing the search and the other supervising the operation from the control room.

The operators must:

- select the “Start” button in the PSS interface
- use a special search badge to enter the tunnel
- follow the entrance procedure described in the previous chapter
- inspect the area, press all the search buttons installed along the path and activate only once the four optical barriers placed along the booster circumference (the barriers guarantee that nobody is following the operator executing the search)
- get out of the tunnel following the provided procedure
- press the “End” button in the PSS interface.

The search procedure for the areas external to the booster tunnel is more simple and can be executed also in the “Booster Shutdown” mode by a single operator.

There is a minimum and a maximum predefined time for each search: the timer starts when the operator opens the door to enter the area and stops when the operators closes the door after pressing the search button/s.

## SAFETY CRITERIA TO OPERATE THE INJECTOR AND THE RING INDEPENDENTLY

The three beam stoppers BST\_BTS1.1, BST\_BTS1.2 and BST\_BTS1.3, installed along the booster to storage ring transfer line, allow operating the injector and the storage ring independently in safety conditions.

If they are all closed, the injector can accelerate the beam even if someone is present inside the storage ring tunnel or if the storage ring is in the “Shutdown” status. In this case the first two beam stoppers (two for redundancy) are used to stop the electron beam and the third to prevent the secondary radiation cascade, produced by the interaction of the electrons with the previous beam stoppers, to channel along the vacuum chamber hole from the BTS\_TL tunnel to the ring.

Vice versa, if one needs to enter the injector tunnel while the storage ring is operating with accumulated beam, the third beam stopper BST\_BTS1.3 must be closed to prevent scattered radiation produced inside the ring tunnel to channel inside the BTS\_TL tunnel.

## BEAM INTERLOCK

The beam interlock is different depending on the radiation hazard “level”.

If someone enters the injector tunnel e.g. forcing a door during beam operations, the PSS:

- switches off the gun
- turns off the preinjector klystron radiofrequency
- switches off both the radiofrequency and the power supply of the RF cavity
- closes the beam stopper BST\_B14.1 (to be sure that no beam remains stored in the booster).

If someone enters one of the booster lateral areas (remaining outside the booster shielding), the PSS:

- switches off the gun
- turns off the preinjector klystron radiofrequency
- switches off the radiofrequency of the RF cavity.

In all of these cases a search must be executed in the violated areas before re-starting operations with the beam.

## PSS ARCHITECTURE

The PSS is based on a PLC system. The choice of a software programmable device has been driven by the complexity of the logics and procedures to implement.

The block diagram of the system is shown in Figure 4: a single CPU is in charge of the execution of the control programs, while a number of distributed I/O peripherals connected through a fieldbus are interfaced to all of the controlled devices. The PSS includes four LCD displays and eleven I/O peripherals, for a total number of 230 digital input/outputs and two serial lines for the badge readers. Connection of the PLC to the preinjector control system [2] is made via an Ethernet TCP/IP interface.

Given the extremely high degree of safety required, strict procedures have been adopted in the system design. Fail-safe versions of PLC (Siemens S7 315F), fieldbus

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(Profisafe) and I/O peripherals have been employed. The general design philosophy has been to use fail safe devices whenever possible and, if not, redundancy and diversification of sensors and actuators have been adopted.

A graphical supervisor running in the control room consoles has been developed to monitor the state of the PSS and allows operators to manage access and search procedures. It communicates with the PLC through a dedicated Tango device server, which is also in charge of logging into an archive database every event related to the PSS. The supervisor is made of a main graphical synoptic and a number of specific panels.

In order to guarantee quick resolution of anomalous situations the supervisor provides operators with comprehensive information on the state of the PSS, including ongoing accesses and search procedures, as well as with significant details of every controlled device and of the PLC internal state machine.

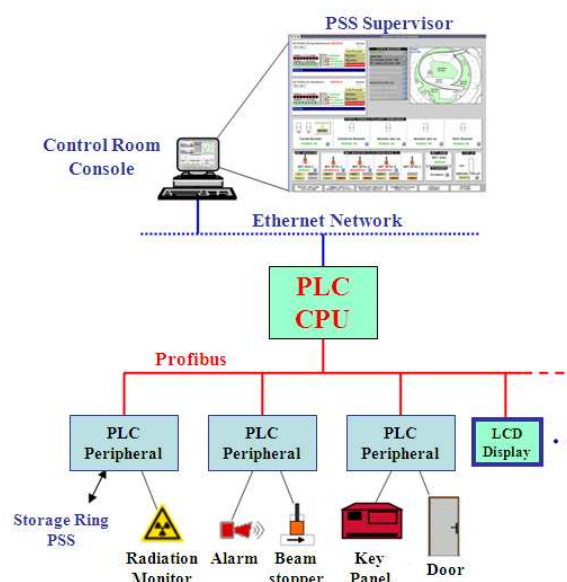


Figure 4: Block diagram of the Personnel Safety System architecture.

## SUMMARY

The PSS of the new injector designed for the Elettra storage ring has been developed taking into account the safety criteria adopted for the pre-existing 1.2 GeV linac and storage ring safety systems. The last version has been tested in January 2008 after the connection of the booster to the storage ring. A detailed user interface has been implemented to allow fast and easy diagnostic of interlocks and alarms.

## REFERENCES

- [1] F. Iazzourene et al., “Elettra Booster Commissioning and Operation”, these proceedings.
- [2] M. Lonza et al., “Implementation and Operation of the Elettra Booster Control System”, these proceedings.

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