TOP-UP IMPLEMENTATION AND OPERATION AT ELETTRA

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Abstract

Elettra established top-up operations taking advantage of its new full energy injector. The safety simulations and personnel safety conditions, the radiation measurements, the implementation and the operations of the whole system are presented and discussed.

INTRODUCTION

The Italian third generation light source (2 / 2.4 GeV) operates for users for sixteen years. In order to stay competitive with the newest light sources in Europe, Elettra was involved during the past few years in a massive improvement program including the construction and set in operation of a full energy injector. Amongst other improvements two 9 mm internal vertical aperture 4.5 m long straight chambers were also installed replacing the 14 mm usual ones. The full energy injector, the upgrading of the beam lines requiring lower vertical gap chambers and the demand for intensity and thermal stability naturally leads towards the top-up operations, whereby the storage ring beam current I is kept at a certain level I_0. This type of operation additionally renders a constant signal to the beam position monitors and great flexibility in intensity manipulations such as constant beam currents in whatever filling bunch pattern and since lifetime is not an important issue allows also lowering the beam emittance and coupling.

At the time being the current stability tolerance given by $\varepsilon = (I-I_0)/I_0$ is defined to be about 3 10^{-3} in the frequent injection mode whereby the injection system is not always active but only when needed to inject.

Since during top-up operations the beam line shutters are open, special care was taken in minimizing the stored beam disturbance and the radiation effects from the injected beam due to various errors that may occur. The critical systems for this are the injection system, responsible for disturbing the stored beam as well as for injecting efficiently and the insertion devices that may reduce the dynamic aperture leading thus to injected beam losses and hence produce radiation. Those two and other issues have been studied in the past [1] and demonstrated that top up is possible for both 2 / 2.4 GeV whereas a measured 120 μm orbit perturbation with a 10 / 6 ms e-folding damping time and 2 Hz repletion rate from the injection system does not seem to sensibly disturb the users .

The full implementation of the top up system including instrumentation, the radiation safety and the interlock systems finished by the end of 2009, as scheduled. At the same time safety simulations were performed. With all systems functioning during the first three months of 2010 all safety checks and radiation protection measurements were performed in order to confirm that the radiation levels in the beam lines are congruent with the radiation norms at any energy.

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SAFETY SIMULATIONS

Simulations [2, 3] were performed to investigate the possibility for electrons to enter the experimental hutches during top up operation. The analysis focuses at first only on the machine segments from the insertion device to the beam line front end. During this first simulation stage, the full Elettra ring is not considered and faults are applied. Successively, the whole machine is taken into account to find if the conditions found on the segments are compatible with a stored beam.

The simulation starts with finding the two phase spaces: the one of the ID and the one of the shutter aperture of the front end. Particles are then tracked forward from the ID (resp. backward from the front end) to the bending entrance. There, if the two phase spaces have a common area, there is a risk of an electron entering the beam line.

Numerous cases of magnet faults were investigated, using realistic magnetic field maps, searching for all extreme conditions for which an electron can enter the beam line. Faults investigations included: one or more quadrupole(s) and/or sextuple(s) turned off or with wrong setting, inversed magnet polarity, correctors wrongly set, wrong beam energy at injection, dipoles power supply fault.

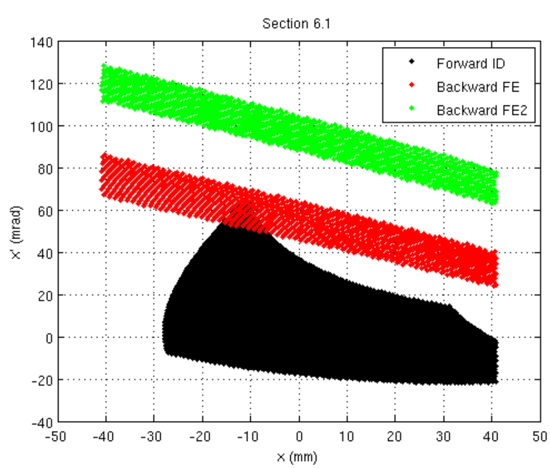

Figure 1: Phase space example at the bending entrance for forward tracked electrons (black) and back tracked electrons for worse case faults scenario and additional dipole fault.

The methodology is to find the combinations of errors creating the possibility for an electron to enter a hutch, then to verify whether these configurations allow the stored beam to be kept. It turns out that even the worse cases do not satisfy a condition for an electron to enter the beam line, except in case of an additional dipole error (Fig. 1)

However for this condition there is no stable orbit found therefore also no stored beam.

The only other case found where electrons can enter the hutches is when there is an energy mismatch of more than 20% between the injector line and Elettra. This is a real danger since the storage ring operates at two energies that differ of about 20% and it is possible to erroneously set the injector at 2.4 and the storage ring at 2 GeV. This situation is avoided by the interlock system as is explained below.

CONTROLS FOR TOP-UP OPERATIONS

In order to satisfy the strict safety requirements of top-operations the system must be able to monitor on a shot-by-shot basis the balance of the net charge extracted from the booster and the charge effectively injected in the storage ring.

A new 24-bit resolution current monitor has been installed in the storage ring. Its reading, which is triggered at every injection shot, together with that of the current at the exit of the booster, is acquired by both the PLC safety system and the top-up supervisor.

The top-up supervisor is a software process that coordinates and controls all the non-safety related operations of the top-up and estimates some parameters which are very useful for the control room operators. Thus it constantly monitors the storage ring current and when the lower current threshold is reached, starts a new top-up cycle: the booster ramping cycle is started and after the time needed to settle the power supplies and other systems to their running values, all the necessary triggers are enabled and injection starts.

During injection the booster and storage ring currents are continuously monitored and the booster charge is stabilized acting on the linac gun grid voltage with a feedback algorithm.

At the same time the supervisor measures the injection efficiency and estimates the "risk" of exceeding a predetermined limit of current loss both on short term and long term basis. If the limit is reached, the safety PLC inhibits the top-up injection as described in the following paragraph. When the desired storage ring current is reached, the supervisor stops the injection.

The application is also used to normally refill the SR and/or perform top-up like injections in top-up off mode. This operation mode is for testing the top-up settings and for vacuum conditioning.

The top-up supervisor is technically implemented as a Tango device server. The operator graphical interface is developed with the QTango toolkit (Fig. 2).

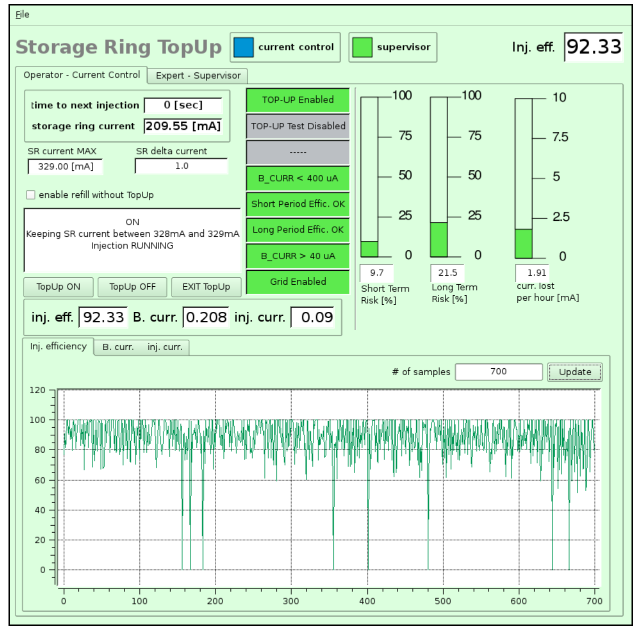

Figure 2: Top-up supervisor panel.

SAFETY CONDITIONS AND RADIATION MEASUREMENTS

To minimize radiation hazards for the experimental hall users during top-up operations, the booster Personnel Safety System (PSS) [4] has been upgraded, introducing new specific interlocks. To enable top-up operations a safety key has to be turned in the position "Top-Up Abi", the ring stored current must be higher than a fixed threshold, the energy of the injected beam must match the energy of the stored beam, the booster current must be lower than 0.5 mA, the short-term and long-term lost current (measured as the difference between injected and stored current) must not exceed fixed limits [5].

From a radiation protection point of view the Elettra experimental hall is classified as "free area" (i.e. an area where radiation dose is less than 1 mSv/year). During top-up commissioning, radiation measurements were carried out to verify the compatibility of this classification with top-up operation. Thus beam was injected into the storage ring with the beam lines safety shutters open and radiation dose rates were measured varying injection efficiency, IDs aperture, booster current, optics parameters (i.e. tunes).

Radiation dose rates were recorded through the network of gamma [6] and neutron monitors placed inside the experimental hall, operating the booster in a continuous top-up injection from a few mAs to the maximum current and interdicting access to the area. Under these conditions local radiation surveys around the beamlines were performed also using gamma and neutron portable detectors.

Measurements were carried out during many machine shifts in order to accumulate a consistent set of data and verify their reproducibility.

The probability of channeling outside the shielding wall the radiation produced by primary beam losses proved to be higher for the beam lines closer to the injection point, that were monitored more carefully with portable detectors to find the position of maximum loss.

As an example, Fig.3 shows the dose rates measured outside the front-end (FE) hutches of the 1.2-FEL/Nanospectroscopy and of the 1.1-TwinMic beam lines, plotted versus the top-up injection efficiency (working conditions: beam energy of 2.0 GeV, booster current of 0.3 mA and IDs closed at 50 mm gap). G18 is a gamma radiation monitor placed just downstream the 1.2 FE hutch next to the vacuum chamber, G39 and N40 are gamma/neutron stations placed laterally to the 1.2 FE hutch at about 90°, G41 is a gamma radiation monitor placed downstream the 1.1 FE hutch next to the vacuum chamber; G43 and N44 are gamma/neutron stations placed downstream the 1.1 FE hutch inside the beam line laboratory.

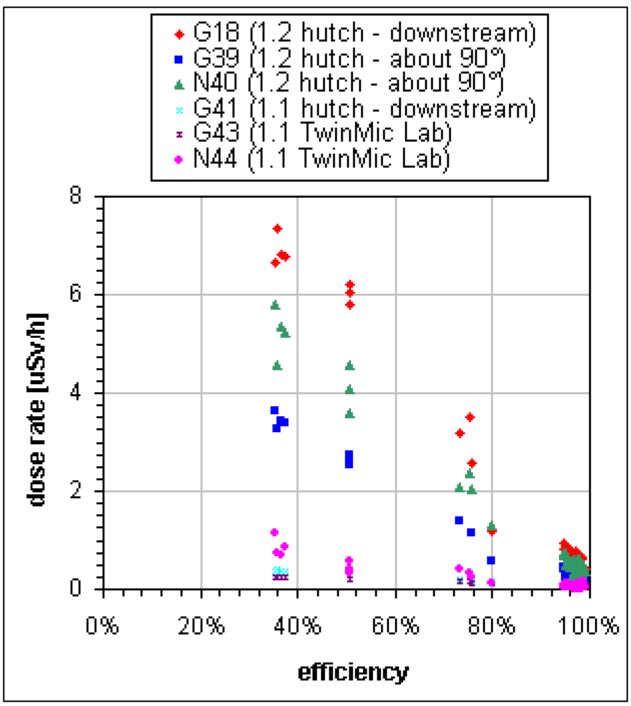

Figure 3: Dose rate measured outside the 1.2 and the 1.1 exit front-end hutches operating the booster in a continuous top-up injection

Graph in Fig.3 shows that for each monitor the trend of dose rate vs. efficiency tends to be linear, and even if measurements can differ a lot in the different positions, they remain less than about 1 µSv/hour for efficiency higher than 90%.

Radiation measurements also confirmed that low injection efficiency can produce around the beam lines dose levels that, if protracted for long, would exceed the dose limit of 1 mSv/ year provided for "free areas".

Therefore the safety limits implemented on beam-lines' radiation monitors and on top-up injection losses have been chosen to face these scenarios and guarantee a *local* and *global* control of top-up process.

In particular, if one of the beamlines' radiation monitors integrates a dose higher than 2 µSv in 4 hours, the beamline safety system forces the closure of the beamline shutter (*local* control of radiation). The alarm is reset at the beginning of the next 4-hours period.

Furthermore, if the limit for the long-term (1 hour) current loss is exceeded, top-up operation is inhibited until the beginning of the following hour; if the limit for the short-term (5 seconds) current loss is overcome, top-up injection is interrupted alerting the operator and requiring his intervention. These two limits assure a *global* control of beam losses inside the machine.

CONCLUSIONS

Top-up operation modality is implemented at Elettra. To minimize radiation hazards, the Personnel Safety Systems both of the booster and of the beamlines were upgraded introducing specific top-up interlocks.

A complex top-up supervisor system was developed to control the top-up process providing a fast diagnostic in case of fault.

Since the injection might eventually disturb some experiments a gating signal system has been implemented.

Top-up operations for users started in May 2010.

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