235th Meeting of the Machine Protection Panel

Injectors topics

April 21st, 2023, via Zoom

Participants:
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The slides of all presentations can be found on the website of the Machine Protection Panel and on Indico (235th meeting).

Minutes and actions from the 231st meeting (Injectors topics)

Daniel recalled that the last MPP meeting on injectors topics was on Novembre 2022 (231st MPP meeting). The minutes are approved, and all the actions have been implemented.

Experience with the SPS DIDT and activation of the BIS connection (K. Li, T. Levens)

Tom recalled the motivation for the implementation of the DIDT. In August 2018, a fast beam loss during slow extraction occurred due to the tune crossing the ½ integer resonance. This resulted in a leak in MBB331, leading to a 48-hour downtime due to the magnet exchange including waitng time for ALARA.

Following this incident, OP requested additional interlocks to protect against fast beam losses: ALPS BPM interlocks, BLM software interlock (faster response) and the DIDT interlock.

The specificationss can be found in EDMS-2038204. They require a fast reaction time with an integration window of 1 ms. A second 10 ms integration window was also specified. Programmable maximum intensity changes for each window are provided. The interlock should have one maskable input to the BIS. A dedicated buffer should record the last 10 000 turns (230 ms) and serve for post-mortem diagnostics.

These requirements imply that the analog “range 1” of the DC BCTs must be used to cover the intensity dynamic range.

A first version of the system has been presented at the 203rd MPP meeting. Two DC BCTs in LSS5 were proposed to be used. Relaxed specifications were proposed, changing the fast integration window to 2 ms (instead of 1 ms) with a total loss threshold increased from 3e11 protons to 5e11 protons. A new development was needed using the BI-standard VFC as the existing VME acquisition was too slow. A 24-bit system for processing will be installed on the surface (as for the LHC DIDT).

The BCT calibration pulse at the start of the SPS cycle (900 ms before injection) serves as a test for the system. The DIDT logic checks these pulses at the end of the 645 ms interlock mask that both windows correctly trigger on this large DIDT, and that the thresholds for both windows have been written (ppm). If this test is not successful, the user permit will be removed before injection.

The 24-bit acquisition system is installed in BA5. As presented at the 231st MPP meeting, a new (unrelated) requirement was added to send the intensity to the SMP. This was developed in 2022. A new "gateware" with general acquisition, DIDT, and SMP features was deployed and tested. As of the 2023 start-up this is considered as an operational system. The noise level has been brought down to 5e10 p/ms.

The short window is a moving average of 5 samples. The long window is a moving average of 50 samples (for minimum noise). This implies a latency of 0.5 ms for the short window and 5 ms for the long window.

The only system settings exposed in LSA are the PPM thresholds for the dump levels. Expert settings exist for the window lengths and averaging factors. These are not PPM. The DIDT results are logged in NXCALS for every cycle.

The gateware and FESA have been implemented and are working well. The noise level is much lower than anticipated. The first commissioning test was done with OP. The MPP approval is requested to enable the BIS input so that OP can start gaining operational experience with the DIDT.

AOB: SPS intensity interlock (T. Levens)

The SPS also has an "intensity interlock" available on both BCT3 and BCT4. Today this is only used for AWAKE, to avoid accidentally extracting multi-bunch beams. It has been used on other cycles in the past.

The intensity is checked 100 ms after the last injection. If it is above or below a set threshold the beam is dumped. Now the comparison is done as a FESA real-time action. FESA then triggers an LTIM with a RDA set. The LTIM output is connected to the CIBU using a special adapter module.

This comparison has now been (re)implemented in the FPGA gateware of the 24-bit acquisition and a second direct output to a CIBU is available.

The proposal is to connect this system to a new CIBU channel in BA5 to replace the existing connections in BA3 and BA4. The advantages are that there would then be a single BCT for the entire intensity range, no software involvement apart from setting the PPM thresholds and this prepares for the obsolescence of the old BCT3/4.

The MPP approval is requested.

Discussion

Daniel asked about the history buffer of the DI/DT in case of dump. Tom replied that the history buffer goes directly to NXCALS. This could also be sent to the SPS QC.

Christoph asked if the example which was presented was a real example and asked what the reason of the losses was. Tom replied that this was a real cycle. Kevin replied that indeed one should not dump due to uncaptured beam at the start of the ramp.

Daniel asked if an analysis of the history buffer could be implemented in the SPS QC in case of dump. Kevin replied that this could be discussed once more experience is gained with the system.

Daniel confirmed that the MPP endorses the activation of the DI/DT connected to the BIC.

Regarding the second proposal, Daniel asked if a CIBU is available in BA5. Tom replied that one is available. The MPP endorses the proposal to enable the system in BA5. An ECR should be prepared to document the changes.

Action: Prepare an ECR for the changes regarding the SPS intensity interlock in BA5 (T. Levens).

MD with high intensity beam for the PSB (F. Asvesta, G.-P. Di Giovanni)

Gian-Piero presented the plans for a PSB MD with high current from Linac4. A new Linac4 source type – IS04 is now installed and operationally used. It is expected to be at least as stable and reliable as the previous version. A reliability test was performed at the Linac4 test stand in 2022. It allows for more current in the RFQ at 3 MeV as demonstrated in 2021. The spares for this source were prepared in 2022.

The original design specifications for Linac4 were for a higher peak current than the 25 mA (out of the RFQ) which is operationally used (70 mA out of the RFQ). To compensate for the lower 25 mA current, the pulse length was extended from 400 μs to 600 μs. These performances are largely sufficient for the LHC brightness. However, for ISOLDE, intensities larger than 4e13 protons are hard to achieve, while the ultimate operational limit is set at 6e13 protons per pulse. One of the objectives for this new source development is also to probe the PSB intensity limitations in the scope of the Accelerator Complex Capabilities WG. No significant impact is expected on the brightness of the LHC beams from simulations. This must be verified with beam.

The original MD plan was to first send more than 30 mA at the end of the L4 and to LBE. Then to inject high peak current in the PSB. The initial request was thus made for 2 dedicated MD slots for Linac4 setup and for 2 dedicated days for PSB MDs at the end of the year. To be noted that the source is not PPM.

During the Linac4 beam commissioning time, time was opportunistically used to start the tests earlier than planned. The source current was increased to 40 mA (35 mA nominal). The source intensity was further increased to 450 mA and 35 mA could be achieved in LBE. Several milestones planned for the MD slots were already achieved.

The Linac4 team would therefore like to inject the beam in the PSB during the 1st dedicated MD slot on May 10. The second dedicated MD slot (June 19) should be only dedicated to Linac4 to explore the peak current reach. The request for the 2 dedicated MD days at the end of the year still holds.

The following applies to the May 10 MD request. The goal is to get feedback regarding the optics and the longitudinal characterization in the PSB.

The super-cycle (SC) would contain 1 cycle every 5-10 cycles. The SC composition would be blocked to avoid uncontrolled programming of the SC with I_BCD. In case a SC change is needed, the following procedure would be followed:

1. Put the beam stopper.
2. Release the I_BCD external condition, program and load the SC.
3. After verification, lock back the SC composition with the I_BCD.

The high current mode will be set in Linac4. The energy spread would be checked as a very important aspect of the tests. The energy spread would also be measured as a function of the debuncher voltage. The maximum number of turns allowed per ring is 100. A special Cruise Control Application will be prepared for the MD to block the number of turns to 100. If time permits the brightness of LHC beams will be measured.

From a machine protection point of view, possible equipment concerns are:

- The new ISO4 source can provide > 40 mA.
- L4 RF: higher power needed; equipment will be interlocked.
- Debuncher amplifier: limiting any tests on longitudinal painting.
- PSB dump: higher intensity per pulse to be mitigated with lower duty cycle. The dump is in any case designed for 1e14 protons per pulse.
- H0H- dump: ring pulse length must be kept below 100 µs to protect the equipment from accidental foil ruptures.
- RF-BI amplifiers: monitoring to avoid saturation.
- Foils have been designed for current higher than 40 mA.
- Loss at high energy on septa or extraction area: no change of interlock thresholds will be made.

No additional risk for the equipment was identified.

Discussion

Christoph asked about the rf power interlock. Gian Piero replied that this concerns the breakdown interlock in case of vacuum spikes with beam losses.

Christoph asked about the SIS protections for the LEBT. Piotr replied that correctors and solenoids will be changed. The limits will be adapted in the operational settings, and not in the MD mode.

Christoph asked why the polarity of the solenoid needed to be changed. Piotr replied that this was experimentally observed at the test stand; this is due to a change in the coupling between the two planes.

Daniel asked if all the parameters that will be changed can be explicitly listed to ease the rollback. Gian Piero mentioned that all changes on the PSB side will be done on clones.
Daniel proposed to prepare a MD procedure which summarises the presented steps including a procedure for the recovery.

Action: Prepare and circulate MD procedure (G. Pi. Di Giovanni).

- The procedure has been prepared, see EDMS-2891121.

Summary of actions

The pending actions from the meeting are:

- SPS intensity interlock
    1. Prepare an ECR to document the changes (T. Levens).