Machine Protection Working Group

Minutes of the 58th meeting, held 22nd September 2006

Present: B. Goddard, E. Carlier, A. Gomez-Alonso, E.B. Holzer, L. Jensen, V. Kain, V. Montabonnet, L. Poncet, R. Schmidt, R. Steinhagen, J. Uythoven, J. Wenninger, M. Zerlauth,

Meeting Agenda:

- Extraction studies for CNGS [V. Kain]
- Machine protection for CNGS : commissioning and operation [J. Wenninger]

Extraction studies for CNGS [V. Kain]

V. Kain presents the results of the tests carried out with beam extracted to the CNGS target (see slides for details). The objective of these tests was to check the available aperture, the verification expected of beam losses and activation in the surrounding area. Most of the measurements were carried out with nominal CNGS beam consisting of two 10.5 μs long batches with nominally $2.4 \cdot 10^{13}$ protons per batch.

By design the TPSG collimator mask constrains the aperture of the TT40 extraction transfer line and shadows the extraction septum (MSE). Through variation of the extraction bump amplitude within the SPS at the TPSG the aperture for the circulating beam was measured to be about 8.3σ (design: 9.3σ), with σ being the nominal beam width. The available aperture for the extracted beam was tested using varying voltages and thus deflection angle of the extraction kicker magnet. The aperture of the extracted beam was found to be about 6.8σ (design: 6.5σ).
The estimated activation levels at the top of the shielding, the adjoining support cavern and its floor are of the same order but slightly higher than the actual activation measured after the extraction tests. **V. Kain** reckons that this may be due to the pessimistic assumptions on the wall thickness of 4.5 m to the neighbouring ECA4 cavern with respect to the actual width between 4.5 and 5 m, the omission of a new additional wall at the exit to ECA4 and possibly the calibration of the radiation detectors that have been performed using an *AmBe* source.

The nominal losses during extraction were found to be between 0.05% and 0.39% depending on the normalisation with respect to the circulating and extracted beam loss pattern, respectively. The gross of beam losses were observed during the first extraction only which **V. Kain** explains by the fact that the extraction kicker cleans the gaps between the batches during the first rising and falling edge of the kicker response. **R. Schmidt** suggests to use e.g. scintillators to further resolve the losses between the first and second extraction. **J. Wenninger** comments that it is difficult to pinpoint the cause for the populated gaps as they originates at injection and could be a result either of the SPS or PS.

Further, **V. Kain** verified the protection and interlock levels of the CNGS transfer line with respect to kicker failures. The missing trigger/firing of one out of five kicker modules is one of the likely failure scenarios. Using low intensity beam, it was shown that the resulting peak amplitude due to an MKE failure is about 10 mm in the transfer line and about 2 mm on target. The target might be able to survive such a failure at top energy. The tests were carried out only till the TED absorber block. **J. Wenninger** comments that more than 10 mm excursion would be required to hit the transfer line aperture and in that in such a case very localised losses are expected.

In the tested case large losses at the TPSG (protecting the septum) were observed but no beam losses in the TT41 transfer line. As **V. Kain** explains, the absence of larger TT41 losses might be attributed to the beam loss monitor gains that were set too high for the given low intensity used for the tests. For nominal operation the BLM gains are set to a low 30mGy threshold.

Machine protection for CNGS commissioning & operation [J. Wenninger]
In his presentation, **J. Wenninger** gives a summary of the commissioning and operation of the machine interlock system used for the SPS and CNGS transfer (see slides for details). A more extensive and thorough summary of the system and performed tests can be found at: https://cern.ch/sps-mp-operation/

The interlock system, providing the protection of the SPS ring and CNGS extraction, consists of four beam interlock controllers (BIC) which are connected through an extraction permit loop. The loop issues a permit signal for the extraction kicker (EXTRACTION_PERMIT = TRUE) in case the input to the BICs indicate a safe extraction. Presently 31 user permit signals are used to compute the extraction permit. The individual permit channels and their mapping to user input boxes (CIBUs) can be found in the slides and above mentioned web page. The input signals can be grouped into three classes based on whether they are based on a continuous survey of a given equipment system or based on the evaluation prior or posterior to an extraction. In case of a post-extraction surveillance the signal is usually latched if a measured beam parameter is out of tolerance to prevent further erroneous extraction. Both pre- and post-extraction surveillance tasks are triggered by machine timing events linked to the main extraction event.

Prior to the performed tests, the description of involved systems and their commissioning procedure has been published in the following two documents:

- LHC-CIB-ES-003: “Interlocked Equipment of the CNGS and LHC Transfer Lines”,
- LHC-CIB-TP-001: “Procedures for the Commissioning of the Beam Interlock System for the CNGS and SPS-LHC Transfer Lines”

J. Wenninger criticises the leak of credibility of the approval based on the lack of approval member's involvement with which these documents where ratified. He notes that, beside the main author and approval leader, the first document was approved by only one and the second by only two members of the MPWGs. He reminds that more people are necessary for the credible approval of machine protection related specifications.

J. Wenninger estimates that the performed commissioning procedures took about 188 hours total. However, not including documentation, repetition of tests and possible amelioration of some repetitive procedures through increased automation, he estimates that these tests could possibly be performed within 3-4 shifts net. Initial commissioning assumptions included about 2-3 weeks for these procedures. The operational manual of all performed tests can be found in above mentioned web-page.

Most of the power converter current surveillance interlock levels were established between 0.1 to 0.5% with respect to their nominal value. Presently, the settings are expert settings and are not yet cycle dependent. It is foreseen to modify this for the next run.

The test of the Fast Magnet Current change Monitor (FMCM) showed satisfying results and yielded interlock tolerance levels that correspond to beam displacements less than 0.5 mm at the target and

within specification (0.1% ripple dependency). Details on these measurements were earlier reported during MPWG meeting #57. Further details on the commissioning of other devices that may generate an SPS or extraction interlock can be found in the slides and above mentioned web-page.

The Safe Beam Flag (SBF) is based on an intensity threshold and used to mask certain systems that enter into the beam interlock system for a more flexible commissioning with safe low-intensity. **J.Wenninger** suggests to increase the SBF threshold from 10^{12} to $3 \cdot 10^{12}$ as this simplifies the production of low intensity beam in the PS, increase the operational efficiency and make the SBF masked thresholds more robust with respect to day-to-day operation. Using the present low threshold may compromise overall safety as people may choose to modify other interlock settings in favour for higher operational efficiency. **B. Goddard** warns about the higher activation involved and advises to keep the old threshold. A lively discussion followed...
It was agreed that further discussion is required and that one should agree on a given threshold prior to the next CNGS operation period.
ACTION: R. Schmidt, J. Wenninger
Post meeting comment: Due to the delayed/postponed CNGS operation this year, it was agreed to postpone the decision and for the time being to keep the SBF at 10^{12} protons per beam.

Based on the CNGS commissioning experience, the r.m.s. extraction stability over 24 hours was shown to be 100 μm in the horizontal and 40 μm in the vertical plane. The larger noise in the horizontal plane can be explained by the current stability of 10^{-4} of the extraction septum (MSE) and energy fluctuations of the SPS radial RF loop. The results are in accordance with the ground motion estimates based on SPS and LEP beam data, and ground motion measurements at the SPS.

Concluding, the commissioning of the SPS ring and CNGS transfer line interlock system was successful and required about 50-60 hours with beam. No major problems were encountered during the commissioning and the transition to high intensity operation was smooth.

The presently commissioned SPS BICs are all interconnected through a common loop similarly as the future LHC BIC system. However, in order to provide more flexibility for the SPS it is foreseen to replace the loop by a so-called 'Master BIC' that will group the four other BICs together. **B. Goddard** enquires how much tests would need to be redone with the Master BIC? **J. Wenninger** explains that the Master BIC logic is more complex due to combination of “ANDs” and “ORs” in its logic. However, the past tests already verified the correct logic of all input interlock devices involved and hence the systematic system test of all individual user system performed this year could be omitted and one could focus on the Master BIC logic alone. In any case, finally a given number of random tests will be performed to re-verify some of the input systems.

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- The presentation of A. Gomez will be postponed to the next MPWG meeting
- **R. Schmidt** reports that the BIC audit has been organised. The outcome will be presented in a following MPWG meeting.