Machine Protection Working Group

Minutes of the 38th meeting held on November 26th 2004

Present: R. Assmann, J.C. Billy, A. Butterworth, E. Carlier, B. Dehning, R. Fillipini, R. Giachino, G. Guaglio, M. Gourber-Pace, C. Ilgner, M. Jonker, V. Montabonnet, B. Puccio, P. Pugnat, F. Rodriguez Mateos, M. Stockner, R. Schmidt, J. Uythoven , J. Wenninger, C. Zamantzas

Excused : R. Denz

Topics of this meeting:

- Post-mortem 'analysis' of the interlock system for the TI8/TT40 tests (J. Wenninger)
- Power Converter surveillance for the TI8 tests (M. Jonker)
- The TT40 beam incident on 25th October 2004 (J. Uythoven)
- AOB

Post-mortem 'analysis' of the interlock system for the TI8/TT40 tests (J. Wenninger)

This 38th meeting of the MPWG was devoted to a post-mortem analysis of the experiences made during the TI8 commissioning and TT40 high intensity beam tests. The first presentation on the interlock system was given by **J. Wenninger** who started by giving an overview of the TI8 tests and of the interlock system and its clients. The interlock system consisted of 4 BIC modules installed in the SPS building BA4 (3 modules) and in SR8 (1 module). A total of 12 interlock client signals were connected to 3 BIC modules, the fourth module having the role of the master module where all signals are combined. The intensity of the SPS beam was limited by two intensity interlocks. One interlock was setup to dump the beam in the SPS after the start of the ramp when the intensity exceeded the pre-defined threshold. A second interlock was only providing an extraction permit if the intensity was below a predefined threshold. For the TI8 commissioning the beam intensity was limited to 2×10^{11} protons in the SPS ring and to 5×10^{10} protons for the extraction. The nominal extraction time within the SPS cycle was at 19400 ms (from the cycle start time). The BIC extraction permit signal consisted in fact of 2 short permits (20 ms duration). The first permit is used to charge the PFN of the extraction kickers while the second permit signal is used to trigger the kicker and extract the beam.

During a high intensity extraction test on the late evening of 25th October a nominal LHC injection (288 bunches, 3.1×10^{13} protons) impacted into the second quadrupole of the TT40 transfer line following a failure of the magnetic septum (MSE). The cause of the failure was a spurious magnet interlock on the MSE power converter due to electromagnetic coupling (EMC) of the high intensity beam signal with temperature sensors of the MSE magnet surveillance system. In reaction to this problem a new interlock channel was added between the PLC responsible for the magnet

surveillance and one of the BIC modules in order to inhibit the beam before sending a power off to the PC. In addition the timing of the PC surveillance was optimized to reduce the time between the surveillance of the current and the actual extraction time from 6 to 2±1 ms.

Problems were also encountered with an interlock on the position of the bumped beam where the tolerance is nominally ±0.5 mm. Systematic position shifts with intensity when switching between high and low intensity were initially as large as 10 mm. This large effect was due to excessive signal amplitudes with high intensity beams. The problem was fixed by adding an attenuator on the signals of the coupler.

EMC effects were observed on the interlock signals under two conditions: when the kicker was firing (EMC on the kicker client signal) and when the MSE PC was switched on. This must be fixed in the future.

The control room user interface was improved, but reading the interlock history by non-experts was still difficult. A new graphical layout will be proposed for the future.

The data logging was extremely useful for the analysis of the interlock system. Two problems were observed. Firstly, about 1 out of 20 logging records was filled with the data from the previous cycle, or was even partly corrupted. Secondly, the masked channels were forced to the PERMIT=YES state in the logging, which prevents an analysis of their inputs.

The importance of managing and logging references and tolerances for interlocks (power converters, BPMs, intensity…) appeared clearly during the tests. The presently available expert programs are not easy to use and do not provide any form of history to reconstruct the interlock settings.

Power Converter surveillance for the TI8 tests (M. Jonker)

M. Jonker explained in details the power converter surveillance system that was put in place for the SPS extractions. The surveillance is implemented as part of the ROCS system that controls the SPS power converters. On a timing interrupt the surveillance process retrieves 1… to N measurements for the PCs of interest and compares the average with a reference and a tolerance. When all channels are in tolerance an extraction permit of programmable length is generated (1 to 255 ms).

A dangerous failure mode of the system is the generation of false permits, which may be due to a number of reasons. In 2004 a number of actions were implemented to reduce the probability of such failures:

- The permit signal now returns to the FALSE state independently of the software process.
- The ROCS processes were simplified.

The best (and independent of the ROCS system) solution is a verification within the BIC (or within the BIC VME crate) that the ROCS signal is in a FALSE state from the start of the cycle until a finite time before extraction.

Following the beam incident (described in detail by **J. Uythoven**, see below), the timing event to trigger the surveillance was moved as close as possible to the extraction time and the sampling was reduced to a measurement (from 10). **M. Jonker** also monitored the MSE current of periods of a few days and observed drifts of the measured

DCCT current within a band of ±0.5 per-mill. For the tests the surveillance tolerance of the MSE was set to ±1 per-mill.

M. Jonker pointed out that more formal testing should be implemented for the interlock systems, similar to what is done for access systems. He concluded that the present system is an acceptable solution for PC surveillance and that the noise levels and current drifts must be understood. A surveillance of HW mal-functioning ('false positives') should be added to the BIC system. In the future it may be possible to integrate this surveillance functionality closer to the hardware.

The TT40 beam incident on 25th October 2004 (J. Uythoven)

Finally **J. Uythoven** presented a detailed post-mortem analysis of the beam incident in the TT40 transfer line. The event reconstruction from the logged data (beam instrumentation, power converter currents, interlock system…) together with FLUKA simulations of the beam impact given a picture that is essentially consistent with the impact position and the observed damage (vacuum chamber cut through over 20 cm). The cause of the magnet interlock that switched off the power converter of the extraction septum was cross-talk of beam induced signals within the PLC that is handling the magnet interlock logic.

Following the incident a number of improvements were made on the interlocks (see previous presentations). The setting up of the high intensity extraction was performed following a more formal procedure and separated from the actual high intensity tests. Lessons for the future:

- Proper commissioning procedures must be established.
- Problems must be solved before proceeding to the next step.
- Full formal testing of all safety related systems must be performed.
- A fast current surveillance system must be implemented for the highly critical extraction and injection elements.
- Passive protection should be placed wherever possible.
- Magnet trips are likely to be correlated with injection/extraction.

Discussions and actions

The discussions around the 3 presentations highlighted the worry around the management of interlock settings. So far the main conclusion is that there are ideas, but not yet clear solutions to the problem. For the SPS multi-cycling makes the situation even more complicated and delicate to handle.

Actions and follow up:

- Management and logging of interlock settings (CO group, LSA project).
- Detection of interlock malfunctioning (ROCS surveillance) by the interlock system (B. Puccio, J. Wenninger).
- Beam position interlock problems (J. Wenninger).
- Septum stability (Injection WG, M. Jonker).

AOB

At the next Machine Advisory Committee there will be four presentations related to machine protection and collimation by **R. Schmidt, B. Goddard** and **R. Assmann.**

The review of the machine protection system will be organized in the spring (April, final date to be confirmed) of 2005. **S. Myers** proposed to invite one person from the nuclear or space industry. He also suggested to organize audits for systems without redundancy like the beam interlock system, the beam dumping system and the beam energy meter.

At the 'Chamonix at CERN' workshop there will be one session devoted to machine protection. In total 10 presentations of the workshop are related to machine protection.