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65th Meeting of the Machine Protection Panel

Participants:
E. Carlier, A. Dabrowski, B. Dehning, W. Iwanski, V. Mertens, G. Papotti, B. Puccio, W. Riegler, R. Schmidt, B. Todd, J. Wenninger, D. Wollmann, M. Zerlauth

1 Presentations

The slides of all presentations can be found on the website of the LHC and SPS Machine Protection Panel:
http://lhc-mpwg.web.cern.ch/lhc-mpwg/

1.1 Issue with timing synchronization SPS/LHC – TDI impact – (G. Papotti)

- During the issue on July 4th 6 bunches were lost on the TDI at injection. The beam came too early for the kicker pulse. The RF in the SPS was on local frequency (not linked to LHC), which caused the bad synchronization. The BQM (beam quality monitor) did not catch this.
- BQM: Automated analysis of bunch length, beam pattern, beam position, etc. If any of these parameters is wrong, the beam is dumped in the SPS (via emergency dump) before entering the LHC.
- The BQM cannot catch such an event as observed July 4th, as it depends on the frequency reference signal. Is the RF frequency switched to local, it receives the local reference, otherwise the linked LHC reference. Therefore the BQM functioned as foreseen.
- The issue should have been caught by alarms: "SPS LHC disconnected". In addition the mismatch was shown on the LHC extraction display "LHC clock disconnected".
- Improvements since the event: LHC RF RESYNCH sequence was introduced into the sequencer, which forces the SPS onto the LHC frequency. In addition Delphine inserted a check in the LHC Injection Sequencer, which checks if the SPS RF frequency is linked to the LHC.
- There is an SPS SIS interlock under development, which will check the locking of the frequency between LHC and SPS automatically.

Discussion:

- Jorg comments, that the deployment of the SIS interlock is a bit delayed, as the expert is on holidays.
- Rudiger asks if it is possible to interlock the MKE if the LHC and the SPS are not synchronized. Jorg comments that this would also affect CNGS (not synchronized) and an extraction into the line up with inserted dumps would be impossible.
- Markus asks how much the 6 bunches have been off, when they hit the TDI. Giulia responds that in this case it were 50us, but as there was no synchronization between the two rings it could have been at any time between 0 and 7 SPS turns.

1.2 Summary of the review on UPS power distribution of the LBDS (F. Formenti)

- The review took place on the 20th of June at CERN, due to some weaknesses that had been observed:
  - Weakness in fault tolerant architecture of the LBDS powering system.
  - Dissatisfactory circuit breaker selectivity of the 230V AC power system.
  - Common mode failure point in a +12V DC powering system (observed during the preparations for the review).
- Reviewers: G. Cumer, W. Iwanski, H, Thiesen, B. Todd, J. Uythoven, M. Vanden Eynden
- The agenda and slides can be found in indico.
- The LBDS consists of 4 main subsystems per beam: 15 extraction kickers, 15 extraction septa, 10 dilution kicker magnets, 1 dump block.
- The review covered the powering of the extraction kicker system.
- The number of asynchronous beam dumps should be limited as high beam losses may occur and cause magnet quenches. Beam losses can occur, if
  - the dump trigger is not synchronized to the abort gap.
  - the abort gap contains too many particles.
  - the MKD kick is not within the defined tolerances.

  - the orbit is locally out of tolerances.
- The LBDS was designed as "SIL4" safety level system:
  - Fault tolerant architecture by built in redundancy.
  - Fail safe actions and components.
  - Continuous remote surveillance and diagnostics of important parameters.
  - Post mortem analysis (IPOC, XPOC).
- First power incident (02.2011): Failure of one Wiener power supply leads to a loss of 1-re-trigger and 1 trigger fan out unit (loss of redundancy) and causes a synchronous or asynchronous dump (dependent on length of PLC master cycle). As mitigation (Xmas 2012) the re-triggering units were connected independently to the EOK107 line. This action avoids the triggering of asynchronous dumps.
- Second incident (April 2012) was caused by a failure in a Wiener power supply (IPOC cPCI crate), without beam in the LHC. Due to a following trip of the EOK107 40A circuit breaker the full system was without power, which would have caused an asynchronous beam dump. A first mitigation was performed in TS1 (April 2012): One re-trigger crate, one trigger fan-out and one TSDS Wiener power supply were connected to the F4 Line (QPS), to implement power redundancy. In addition 2A fuses were added to the Wiener power supply mains connections to assure the selectivity of failures.
- A single point of failure was discovered: 12V common mode coupling in TSU crate. If a short circuit happens inside a VME crate, it affects both Wiener power supplies. A long fault will cause a complete switch off of the +12V, which would mean a complete loss of the triggering capabilities of both TSU units. Neither a synchronous or asynchronous dump could be initiated. For this case the fault tolerance is not sustained. As mitigation an external survey of the +12V crate line was introduced, which will directly trigger an asynchronous dump via the re-trigger in case of failure detection.
- Fully double redundancy power distribution (2 different UPSs to TSDS) was introduced, but the problem with full selectivity still persists. In

addition special attention needs to be taken for the QPS clients at the F4 Line. For LS1 it is planned to connect the redundant LBDS, the QPS and other clients to separate power lines (EOD1/65) to achieve better protection by partitioning. In addition more reliable circuit breaker selectivity shall be achieved. Furthermore the power distribution inside the racks will be improved using crate power distribution boxes (as applied and qualified for LHCb).

- Wiener power supply failures: The Power Factor Corrector – a kind of filter – is the weak point of these power supplies, with failure rates of 2%/year (as predicted by the manufacturer). The manufacturer introduced a by-pass diode (D2), to protect the PFC. Although intensively tested by PH-ESE the effectiveness of the modification could not be confirmed, as the failure couldn't be reproduced. Thus, the reason for the PFC failures in the experimental zones still remains unclear. These types of failures could lead to significant down time. BE-CO currently is investigating the ELMA CPA500 power supply, which could become an alternative to the Wiener power supply. It is recommended to join efforts of BE-CE, TE-EPC and PH-ESE for qualifying new power supply solutions.
    - Ben comments that the quoted power supply has a different architecture and size, which complicates a possible replacement.
- Proposed (LS1) solution for the TSU +12V common mode failure: Implementation within 3 separated VME crates (TSU_A, TSU_B, Trigger Synchronization Interface [TSI]). The TSI crate will then still be a point of single failure, but as this belongs to the fail-safe area it would only cause a synchronous dump. The correct implementation of fail-safe and fault tolerant concepts should be studied for the whole LBDS to avoid other problems.
- Proposal for fail-safe asynchronous beam dump through BIS: Implementation of a delayed triggering (250μs) of the LBDS re-triggering lines (RTL_A and RTL_B) by the BIS, in case the BIS loop is opening. This would provide a fail-safe triggering of an asynchronous beam dump, if the LBDS doesn't perform a synchronous dump before.

  - Markus comments that, a fail-safe implementation of this additional BIS input could trigger more asynchronous beam dump.
  - Ruediger responds, that we shouldn't try to avoid asynchronous beam dumps by any means. We should be able to survive asynchronous beam dumps. The system is designed to have one per year. Fabio comments that the link from the BIS should better be called *robust* instead of *fail-safe*.
- Proposal of surveillance of the redundant features: All redundant features should be monitored and as soon as a redundant feature is lost a synchronous dump should be triggered, to minimize operation time at high risk.
- Power failure tests: New studies based on the configuration with the UPS_A, UPS_B and the triplicated TSDS crate have been initiated and 7 power failure cases have been studied. A reference document with the final architecture listing all failure predictions and on-line test validations needs to be produced.
- A number of questions concerning the future LBDS power commissioning should be clarified:
  - Will the tests be performed remotely or local or as a combination of both?
  - How to maintain the diagnostics available?
  - How to perform power failures? Is there a need for additional (temporary) circuit breakers?
  - How to avoid shutting down other LHC protection systems?
  - Frequency of the LBDS power commissioning tests (after LS1, winter shut downs, technical stops, …)?
- Conclusions and recommendations of the reviewers:
  - Quickly implemented bug fixes were appropriate.
  - Use BIS for triggering delayed asynchronous dump.
  - Modify UPS electrical distribution and upgrade circuit breaker technology.
  - Modify TSDS architecture.

  - Survey the power availability of all power converters and inside the crates.
  - Study alternatives to Wiener power supplies.
  - Update the LBDS safety study and define validation criteria.

Discussion:

- Bernd asks if a modification of the Wiener power supplies is possible. Fabio answers that there is still work ongoing into this direction, but in parallel one should study an alternative solution.
- Etienne asks if the replacement of switching mode PS by linear power supplies was discussed, as e.g. only ~15% of the power available through the Wiener is used. Fabio answers that he isn't sure if there is an appropriate linear power supply commercially available.
- Markus comments that we should try to combine the needs and efforts for power supplies of different systems. Maybe it then would make sense to adapt a commercially available power supply to our needs and replace the Wiener power supplies.

1.3 Plans and resources needed for follow-up of LBDS UPS powering review – (E. Carlier)

Actions that can be done before the end of LS1:

- Connection of BIS to LBDS Re-Trigger lines: It may be possible to re-use the same hardware to send a pulse from the BIS to the 250μs delayed re-triggering lines. After each dump the XPOC needs to check that both pulses (the normal and the delayed one) arrived. Only then a new injection can be allowed. Relatively easy implementation, which increases safety substantially. Involved groups are TE-ABT, TE-MPE and EN-EL (for details see slide 4).
  - Markus comments that this mitigation has been discussed earlier and should now be implemented. It still needs to be discussed with Reiner and Bruno et al, who is taking the action from the TE-MPE side. Ruediger adds that we definitely should introduce this change before re-start after LS1.

- Consolidation of UPS distribution within LBDS: Introduce additional 13A UPS line to power the triggering boxes redundantly. Involved groups are EN-EL and BE-CO (for details see slide 6).
    - Markus asks why we need a completely new EOKxx line and cannot use the 230V distribution box? Etienne responds, that the request for this separate line still needs the approval of EN-EL.
- Modification of TSDS architecture and study replacement of Wiener power supplies. Involved groups are TE-ABT, BE-CU, TE-EPC and PH-ESE (for details see slide 8).
- Implementation of secondary voltage surveillance: to be developed and connected by TE-ABT. The remote surveillance needs to be implemented by BE-CO (for details see slide 9).
    - Ruediger comments that taking into account the delayed BIS triggering of an asynchronous beam dump, we need to discuss if the implementation of the surveillance should directly cause a synchronous dump or if we should run and address the problem after the next dump. Markus asks if we know how often a loss of redundancy takes place. Etienne responds that so far only one comparable event has been observed during technical stops. The operational application needs to be discussed in parallel to the implementation of the surveillance.
- Others (see slide 10):
    - Review integration of BLMDD within TSDS and study the impact of the new TSDS configuration on reliability (TE-ABT, BE-BI).
    - Perform study to predict the consequences of different types of powering failures. Still waiting for response from EN-El. (TE-ABT)
        - Markus comments that intensive testing is very lengthy, but maybe it would be helpful to introduce additional tests for Pt 6 during the yearly tests.
        - Ruediger mentions that one should ask if the introduction of (non permanent) switches/circuit breakers for these test would be possible.

- Define test procedures for a full re-commissioning of the LBDS powering after LS1 and major maintenance activities (TE-ABT, EN-EL.

Discussion:

- **Action:** TE-MPE shall provide in collaboration with ABT the redundant link from the BIS to the re-triggering lines of the LBDS.
- **Action:** The LBDS UPS powering upgrade should be re-addressed in MPP next year to report on the status of the mitigations.
- Bernd asks how it is planned to study the failure cases. Etienne responds that these studies will be based on earlier studies, where cases will be added. Bernd mentions that a technical student will look into these types of studies for the BLM team from early 2013 on. Ruediger comments that these studies could probably be added to the availability study group, including Andrea, Ben et al.
- Wiener power supplies: Ben comments that the performance of the Wiener power supply (2% failure rate) is better than promised by the manufacturer. A solution could also be to replace the content of the power supply with some other commercial devices.
- The outcome of the LBDS review will be presented in the LMC. Markus comments that EN-EL should be informed as early as possible of the extra work from this.

1.4 Miscellaneous

- Temperature increase in the stainless steel foil of a Roman pot due to the impact of a nominal bunch (Action from the 63rd MPP): A. Lechner prepared a slide, which shows that the difference in deposited energy between his simulation and a previous study, cited by M. Deile, is mainly due to an about 10x smaller beam size assumed in the latter and different beam energies (4TeV versus 7TeV). The 30μm vertical beam size in the study cited by M. Deile is for an optics with $\beta^* = 1540$m at 7 TeV.
- Markus presents the new Action list of the MPP website. This page gives an overview of all actions from the past meetings and their current status.

- CMS solenoid: Recently a fast power abort of the CMS solenoid caused increased beam losses, which then lead to a beam dump. So far a ramp down of the solenoid was considered as reasonably transparent to the LHC beam. Due to the recent experience it should be studied if a fast power abort of the CMS solenoid should trigger the CMS beam permit.
  Action: Discuss with N. Bacchetta in September.