149th Meeting of the Machine Protection Panel

Participants: A. Antoine, J. Boyd, R. Bruce, F. Burkart, X. Buffat, D. Lazic, B. Lindstrom, T. Persson, M. Pojer, R. Schmidt, I. Romera, J. Uythoven, M. Valette, J. Wenninger, C. Xu, C. Zamantzas, M. Zerlauth.

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

1.1 FMCM commissioning and first operational experience with new converters (A. Antoine)

- Alain presented the results of the FMCM commissioning with the new power converters. In 2017, 22 dumps were caused by electrical glitches seen by the FMCM but not impacting any other systems. This lead to the replacement of the RD1 converters in IP1 and 5, and the RD34 converters in IP3 and 7. The hardware modifications from the FMCM point of view were minimal. Due to the necessity for the FMCM to be able to monitor the old converters, in case a rollback was needed, the FMCM connection HV-box was moved after the load switch.
- An issue came up with RD34.LR3 where the measured voltage (U_mag) did only correspond to half of the expected level, which prevented the correct interlocking functionality at injection current. The problem was identified as a bad crimping of the HV cable, leading the amplifier to see only half of the voltage. The connection was restored by moving the cable, but was unstable. The HV box and the cable were replaced. As a consequence, all FMCM signals were checked and a ratio 2 of the measured signal to the theoretical one was also found for RD34 in IP7. Another issue was also identified on RQ4 in IP3 with a different signature, it will be investigated in TS1.
- The FMCM tests were performed successfully on the 15th of May. So far in 2017 there were four dumps from the FMCMs, mostly on septum magnets but these glitches are also affecting a lot of systems across the LHC. No glitches lead to triggers on the new converters, even with perturbations with similar amplitudes as last year.
    - Hugues asked what would happen if the connection of one of the HV cables was lost again. If it happened while the converter is being powered, a beam dump would be issued, otherwise it would not be detected. Markus added that the system was commissioned with a missing contact in the past, now that this problem has been identified it will be checked for in future commissioning. Ivan added that a check could be added in IPOC to verify the voltage is not half the expected one. The reading will depend on the beam energy but it can be done.

1.2 Simulation results of D1 / D34 powering failures for ATS optics and possible consequences on thresholds (M. Valette)

- Matthieu presented an update on the simulations of RD1 and RD34 failures with ATS optics. The analysis of FMCM trigger events showed that due to the different behaviour of the new power converters the trigger would happen within 5-6 LHC turns from the beginning of a failure. This also means the dI/dt and the orbit change will grow faster in the beginning of a failure.
    - Markus commented this comes from the active filtering, the dI/dt will oscillate and converge to an exponential decay.
- The simulations were performed using a linear tracking code. The resulting orbit change in case of a failure fits the BPM measurements during the tests but the losses need orders of magnitude scaling.
    - Christos commented the PostMortem data in Grays per seconds might not be relevant for such a benchmark and the wrong scaling might come from the integration time of the BLMs not being taken into account.
- The situation at injection and flat top are safe due to the small β-functions at the D1, RD34 failures are similarly safe thanks to the small β in IR3 and 7. In collisions at 40 cm with the larger β, the FMCM should trigger 10 turns before reaching damaging losses with a full beam. In case of a combined failure of both RD1 in IP1 and 5 the BLMs would very likely trigger before the FMCM. Nevertheless, the FMCM would still trigger before the damage limit is reached in the IP7 collimators. In conclusion, the current thresholds give sufficient protection to the LHC assuming the operational emittances and halo densities. Higher tail populations would result in lower margin, beam scrapings showed significantly higher tail populations than the previous Van der Meer scans.
    - Rudiger commented the worst case scenario is having a cut off halo, in that case the BLMs are not fast enough and it is exactly what the FMCMs are meant to protect against.
- With ATS optics at 33 cm β*, the damage limit of 1MJ on a given collimator jaw is reached 8 turns after the FMCM trigger, 5 in case of a combined failure. The limit assumed currently is three turns between opening the BIS loop and the dump, the FMCM thresholds might have to be tightened before going to 33 cm.
    - Roderick commented that some damage calculations could be done to estimate more precisely the damage limits in this scenario, which is slower than an asynchronous beam dump and with more diluted beam, which leads to a higher damage limit.
    - Markus commented that the electrical glitches are not the only concern, one might want to review in light of the new optics inter-turn shorts and different failure cases in the D1 magnet and the resulting signals on the FMCM.

Action (MPE-PE): review other failure cases for RD1 and estimate the associated FMCM signals.

1.3 ADT -AC-Dipole mode: results of parameter validation measurements (B. Lindstrom)

- Bjorn presented the results of the ADT AC-dipole mode tests performed in May. An orbit excursion of 2 σ can be reached in 30 turns, the goal is to define the limits in settings for the operational performance of tune and coupling measurements.
- The measurement suggests there is a saturation of the ADT voltage above 7 kV. A discrepancy between measurements and MAD-X simulation requires more investigation but the beam orbit change as a function of the excitation parameters was fitted and limits can be derived from the measurements.
- A test was performed to excite two pilot bunches with the maximum strength of 7.5 kV. The beam was dumped by BLMs after 45 turns. The extrapolation from the measurement suggest that the damage limits could be reached after 55 turns, leaving a margin of more than 10 turns between triggering a dump on losses with pilots and damage with a full beam. Therefore, the BLMs provide adequate protection.
- The orbit offset required for the tune and coupling measurements were translated to ADT settings for various excitation scenarios.
    - Xavier and Tobias commented they want to perform these measurements away from the tune resonance so the actual excitation should be slower and lower (although for the worst case one has to assume the possibility of excitation on the tune). Bjorn answered that no significant difference was measured when exciting 10^{-2} away from the tune. This might come from uncertainties in the tune measurements and a difference is certainly visible further away from the tune.

1.4 Status of IQC and future development (M. Pojer)

- Mirko presented the status of the IQC which now includes a dBLM tab to display and assess the injection losses. The losses on the TDI and TCDI are available with two different gains in order to resolve losses with different levels. The MKI waveform is also indicated to discriminate between longitudinal and transverse losses, the alignment was made from calculations. The MKE waveform is not saved to PM and is not available.
    - The HI and LO gain channels' names should be switched.
- Future developments include a reference screenshot of "normal" losses to help the operators with the interpretation of the dBLM readings. The data is available with high resolution and a zooming option was implemented, allowing to identify the problems in beams production. In order to improve performances and loading time, the data was reduced to 2000 points (2 ns resolution). A resolution of 1 ns could be made available but is not needed from an operational point of view.
- The standard BLM measurements panel should be reviewed in order to make the colours more relevant and indicate the direction of the beams. Some loss amplitudes now appear in red in situations where the injection should not be

discarded. The longitudinal losses for example don't scale with the number of bunches being injected.

- Rudiger commented it is the first time the diamonds start to be used operationally on a daily basis. They are for the long-term a promising solution for integration in the machine protection architecture to allow interlocking with faster reaction times for some specific failure cases. Christos commented that there is a lot of experience coming also from the LHC experiments on these devices, but the integration in the protection system would be a long-term effort.

1.5 AOB: Beam dump due to trip of the RQS.A81B1 circuit (16.06. 18:00) --> circuit strengths and plans to interlock trip via PIC (A. Antoine, M. Valette)

- Alain gave a summary on the necessary changes to include the skew quadrupoles into the maskable interlock family of the Powering Interlock System (PIC). In the family of skew quadrupoles, the ones in the triplet (RQSX3) are currently the only interlocked ones since the YETS 2015, the arc ones (RQS.Axx, RQS.Lx and RQS.Rx) now have no impact on the PIC and the BIS.
- A recent trip of RQS.A81B1 (due to a power converter failure) caused losses that eventually lead to a dump. These circuits could be added to the maskable interlocks in PIC if such trips cannot be survived anymore without losses above threshold. A proposed date to implement this is towards the end of TS1. Powering tests would be required after changes for these circuits.
- Matthieu then gave a summary on the event from June the 16th 2017 and the integrated skew focussing associated with each circuit. In 2016, the coupling correction was more or less global for both beams. In 2017, a patter appeared and the loss of RQS.A81B1 which is more strongly used for coupling correction lead to a beam dump by BLMs in IR7. A proposal is to integrate all circuits with integrated strength above 40 (see slides) to the interlocking, to be reviewed after changes of optics and correction schemes.
  - Markus commented the dependence on optics is difficult to implement and the RQSX are now interlocked although they have lower strengths than the previously mentioned limit and have led to dumps in the past.
  - Rudiger added that if the circuits were not lost too many times in the past and it might not influence availability, all 24 circuits should be interlocked.

Action (Matthieu): determine how many times the RQS circuits went into fault in the past year.

Action (MPE-MI): make a final proposal for the change in TS#2 via an ECR.