Machine Protection Working Group

Minutes of the 3rd meeting held on May 11th 2001

Present: J.C. Billy, F. Bordry, E. Carlier, E. Ciapala, B. Dehning, J. Dieperink, M. Gyr, J.B. Jeanneret, J.F. Juget, S. Di Luca, V. Mertens, G. Mugnai, J. Pett, B. Puccio, M. Sassowsky, R. Schmidt, F. Szoncso, J. Wenninger

Excused: E. Cennini, R. Denz, L. Serio

Main topics of this meeting:

- Introduction and report from other meetings (R. Schmidt)
- Beam dump system : overview and requirements on energy tracking (M. Gyr)
- Beam dump septa magnets : overview and fault scenarios (M. Sassowsky)
- Energy information & septa magnet surveillance (J. Pett)
- Glossary (R. Schmidt)

Introduction and report from other meetings (R. Schmidt)

R. Schmidt informed the working group that the MPWG mandate had been presented at the LCC and TCC. **T.Taylor** stressed that the MPWG co-ordinates the activities of several teams/groups, but that the responsibility for the systems (quench protection, beam dump, etc.) must remain in the groups. No other major comments have been received.

At the LCC two topics that concern the MPWG will be discussed in the near future. Once point concerns quenches in the inner triplet, the other point concerns injection scenarios and adjustments. **R. Schmidt** suggested that aspects of injection related to machine protection be discussed inside informal preparatory meetings and presented to the MPWG.

Two informal meetings have taken place since the last regular meeting of the MPWG. The minutes and presentations can be found on the MPWG homepage under “Documents”. **M. Gyr** mentioned that there an academic training series on Reliability will be organised for next year. The speaker will try to integrate aspects specific to LHC.He will visit CERN before the lecture series to learn more about LHC reliability aspects.

The MPWG homepage is now accessible from the LHC Working Group page.

Beam dump system : overview and requirements on energy tracking (M. Gyr)

An overview and some of the requirements of the Beam Dump System were presented by **M. Gyr**. For each beam, the active elements of the dump system are :

- 14 kickers (MKD) providing a 0.26 mrad horizontal deflection.
- 15 magnetic (Lambertson) septa (MSD) providing a vertical deflection of 2.4 mrad. The gap of the septa magnets is ~ 44 mm wide.
- 10 horizontal and vertical diluter kickers (4 MKBH, 6 MKBV).
- The graphite beam dump block (TDE) with a core diameter of 70 cm.

Energy tracking is required for all active elements. The MSD is in that respect the most critical, since the kick must remain constant within 2%. The diluters must track reasonably precisely. As an example, if the diluters would be at full their strength for a beam dump at an energy of 450 GeV, the beam would miss the TDE, which is not acceptable. At 7 TeV on the other hand, 9 out of 10 modules of the dilution kickers could fail without catastrophic consequences (still, this should be avoided). The energy information could be obtained from the dipole (MB) current, while corrections for effects such as saturation of the MSD, non-linearity, etc. must be taken into account "somewhere" (in a system that needs to be defined).

A large number of failures have been taken into account in the design of the beam dump system. In such an event the system would still be "operational", but the dumps will not be clean. An example is a beam dump when the dump kicker is not synchronised with the beam-free gap. In such an event parts of the beam would hit the edges of the MSD. A ~ 5-6 m long and 23 mm wide graphite absorber block, the TCDS, is used to protect the thin, 6 mm wide (for the first magnets) steel sheet that separates the extraction channel from the normal beam pipe. The TCDS should not be destroyed in the event of such an unsynchronised dump.

The aperture of the MSD extraction gap is nearly fully used (3-4 mm margin) taking into account the following effects or errors :

- The kicker flat top has a 7% variation in kick strength.
- The closed orbit can have a distortion of up to ± 2 mm.
- 1 out of 14 kickers may fail.
- 20 % betatron function beating.
- The (finite) beam envelope.

The energy tracking of the MSD must be maintained within ± 2% maximum in order to remain inside the vertical aperture of the diluter kickers and to hit the graphite core of the TDE. Contributions to this energy tracking come from :

- The tracking error of the power converter and the uncertainty on the dipole calibration curve account for 1%, which is rather conservative.
- In case of a PC fault, a 1% margin is reserved to give a 20 msec reaction time to dump the beam before the current in the MSD decays.
- Load errors due to short circuits.

M. Gyr concluded that :

- The MSD current must be tracked within 1%.
- A load surveillance of the MSD is necessary.

- A dump must be requested whenever the current for the MSD is "out of tolerance".

Beam dump septa magnets : overview and fault scenarios (M. Sassowsky)

M. Sassowsky presented the MSD magnet design. A first MSDC prototype build by IHEP has been recently accepted for shipment to CERN (there are 3 types of MSD magnets [A,B,C] with slight different geometry). The magnets present a ~ 3% non-linearity in integrated field ∫Bdl when approaching saturation. The field is homogenous inside the gap within ~ 0.1%. At a current of 880 A, which corresponds to the setting for a beam energy of 7.5 TeV, there is a 20^{o} C gradient between inlet and outlet water temperature. The temperature protection is made with thermal switches that open when the temperature exceeds a given threshold (~ 70^{o} C). In the event of a cooling failure, it will take 15 minutes for the magnet to heat up by 40^{o}, which is clearly not time-critical.

The magnet coil consists of 6 layers with 8 turns each for a C-type magnet (4 layers for A-type, 5 layers for B-type). The layers are electrically in series and hydraulically in parallel. The voltage drop over a layer is 6 V for a layer resistance of 6.8 mΩ @ 880 A. The time constant of the magnet is ~ 2 s, for example in case of a PC fault. The 15 MSD magnets taken together consist of 600 (individual) turns. An inter-turn short circuit within one layer will result in a reduction of the field by 1 part in 600 (~ 0.2%) which is acceptable. If a short circuit develops between 2 adjacent layers the field reduction may be as high as 16 parts in 600 (2.7%), which is above the acceptable limit. This is to be considered as an extreme worst case, since it is very unlikely that a short-circuit will actually result in a zero resistance. From experience it is known that such short-circuits develop slowly and could be detected before the field integral is out of tolerance. Among the possibilities to monitor the magnet load, the voltages between layers could be compared (to reduce systematic problems due to temperature induced resistance changes).

Discussion: **J. Pett** mentioned that ideally one would like to detect the high frequency dV/dt signals that usually come along with short-circuits. **B. Dehning** asked whether it was not possible to directly measure the field with NMR probes. **M. Sassowsky** said that so far this has been ruled out because the area was considered too activated. Finally **M. Sassowsky** insisted that reliability requirements have been taken into account and that mechanical shear stresses due to thermal dilation are avoided with this coil design. One test coil was submitted to a thermal cycling test (50 cycles between room temperature and 90^{o} C) and passed the subsequent electrical tests. More ageing and cycling will take place when the magnets arrive at CERN.

Energy information & septa magnet surveillance (J. Pett)

J. Pett presented some aspects of the standard PC Dico (Digital Control) functionality. Internal and external faults are monitored at a 10 msec rate dictated by the WORLDFIP bus. Two DDCTs measure the PC current every msec, the results being published every 10 msec over WORLDFIP. Faults are transmitted to the interlock systems with delays that must still be defined, but which will be in the msec range. Special features can be provided for the beam dump system :

- The reference and measured (DCCT) currents could be compared and a signal send out if the difference exceeds a given threshold. The time response would be ~ 5 msec, which is adequate for the MSD where the reaction time is ~ 20 msec.
- "Copies" of the MB analogue current could be made (but beware of cable lengths).

In terms of reliability Dico has many failure mechanisms since it consists of large amounts of software. There is for example no watchdog to detect "hangups". In addition such a watchdog would probably have a slow response time. The MSD PCs require some additional devices to enhance its reliability.

Discussion: Concerning the question as to whether information from all 8 sectors is required, **R. Schmidt** said that the current reference could come from the two sectors adjacent to point 6 only, since there will be 4 MB DCCT signals available. It is not necessary to combine measurements from all 8 sectors since they must agree within some 0.01% ! It seems clear that some special equipment is required, and this must be decided soon. This equipment will be "interfaced" to a few groups (SL/BT, SL/PO and SL/MS). It seems more or less clear that the standard PC solution is not adequate for the MSD, since we would like to steer this magnet from the MB current. It was decided that some discussions will be organised in the near future among those that are concerned to propose solutions (**Action : R.Schmidt and J.Wenninger).**

Glossary (R. Schmidt)

A glossary of terms used in the machine protection systems was proposed (see appendix). The question of the responsibility for the extraction switches for 600 A that are directly triggered from the PC, and the water cooled cables from the PC to the DFB was raised. Are they a part of the power converter system, or outside? (to be clarified – **Action: R.Schmidt)**

Proposed glossary :

- **MACHINE PROTECTION SYSTEM**

Generic Name to distinguish the EQUIPMENT PROTECTION SYSTEM from the system to protect people (INTERLOCK / ACCESS SYSTEM)

- **BEAM DUMP SYSTEM**

includes all elements that are required to dump the beam after delivery of a BEAM DUMP REQUEST - SL-BT

- **POWER CONVERTER SYSTEM**

Includes all power converters (what about warm cables, and about energy extraction systems?) SL-PO

- **BEAM LOSS MONITOR SYSTEM**

System of beam loss monitors, along the arcs, and in the insertions - SL-BI

- **ACCESS SYSTEM**

System to provide access for people, for protection of personnel - ST-AA

- **QUENCH PROTECTION SYSTEM**

System that protects all superconducting elements - LHC-ICP

- **BEAM INTERLOCK SYSTEM**

System to enable BEAM PERMIT and issuing BEAM DUMP REQUESTS includes the distributed electronics around the ring and the optical links

- **POWER INTERLOCK SYSTEM**

System for protecting the superconducting elements and several warm magnets, to enable and abort powering of electrical circuits (includes POWER PERMIT and POWER ABORT electronics and links, but not interlock elements inside power converters, neither the interlocks within the Quench Protection System) - SL-CO + AC-TCP

- **POST MORTEM SYSTEM**

System for recording data from various instruments after POWER ABORT or BEAM ABORT - Controls Project