Machine Protection Working Group

Minutes of the 51rd meeting held on October 28th 2005

Present: F. Bernard, B. Dehning, R. Denz, R. Filippini, R. Giachino, R. Lauckner, H. Milcent, V. Montabonnet, B. Puccio, R. Schmidt, R. Steinhagen, B. Todd, J. Uythoven, J. Wenninger, M. Zerlauth

Topics of this meeting:

- Report from the SubWG on Reliability
- Handshake between PIC and QPS for powering electrical circuits - software interlocks
- AOB

Report from the SubWG on Reliability (R. Filippini)

R. Filippini presents the results of the sub-working group on reliability and the underlying methodology (see slides and MPWG minutes #40 for more details).
The group's mandate is to analyse the dependability of the Machine Protection System (MPS) and to potentially identify 'weakest links' inside the system that need potential improvements. The analysis, based on a simplified MPS, consists of the following elements:

- Beam Loss Monitors (3500 monitors),
- Quench Protection System (4000 channels),
- Powering Interlock Controller ,
- Beam Interlock Controller and the
- Beam dumping system (2).

The model includes the internal system surveillance that, in case of detected system failure, issues a fail-safe operation abort. The associated beam dumps are referred to as 'false dumps'.
Safety and number of false dumps per year are deduced or each system separately and depend the following three parameters:

- dump request apportionment
- redundancy internal to the BLM and
- cross-redundancy between the BLM and the QPS for slow beam losses.

As a working assumption, the following operational scenario is assumed: 200 days with 400 LHC fills (10h). Each LHC fills is followed by 2 hours for system checks that return the system in a "as-good-as-new" state. Dump request are apportioned into 60% planned, 15% due to fast beam loss, 15% due to slow beam loss and 10% due to other causes.
The present estimate for the total MPS un-safety, assuming no internal BLM redundancy, is approximately $5.8\cdot10^{-8}$/hour which complies with the SIL3 requirement. The number of false beam dump requests per year is estimated to be 41±6.
It is demonstrated that the system un-safety strongly depends on the internal cross-redundancy within the Beam Loss Monitor System and the apportionment of dump requests. If the assumed apportionment is modified to for example '20:45:25:10' the resulting estimated MPS un-safety would yield SIL2 and does not fulfil the MPS SIL3

requirement. If the BLM redundancy is accounted for, the estimated safety complies with SIL4.
R. Filippini points out that the initial group mandate, the analysis of a simplified MPS, has been accomplished. The system safety has been assessed between SIL2 and SIL4 depending on the BLM internal cross-redundancy and dump requests appointment. The same quantity also depends on the effectiveness of post mortem diagnostics (off-line) and fault detection (on-line) as it has been demonstrated for the MKD system of the Beam Dumping system.
The average number of false dumps is within 10% of the total machine fills and it is independent of the dump request apportionment and BLM cross-redundancy. The results strongly depend on the accuracy of the components failure rates that have been estimated according to the military handbooks, which is conservative by nature. For this reason both un-safety and number of false dumps could have been overestimated. A list of topics to be further investigated has been provided (see slides).
B. Dehning notes that the uncertainty of Beam Loss Monitor (BLM) placement is presently not included in the analysis. He suggest in case of a further evaluation that a priority list should be established, containing devices that have not been yet included in the presented estimates, as for example the Beam Energy Meter (BEM) data distribution to the BLM system.
It was agreed, that the Beam Energy Distribution should be added to the model analysis. First results are expected before the end of the year.
R. Schmidt points out that the coming LHC hardware commissioning is a good opportunity to collect data (statistics) on hardware failures that could be analysed and used to validate the presented dependability calculation (SIL and false dumps). He stresses that for this purpose, a full and consistent data acquisition, especially with respect to timing, is important and should be coordinated for instance through the Hardware Commissioning Working Group.

R. Schmidt proposes a meeting on the topic “What could we learn from LHC Hardware Commissioning for the reliability assessment”, with R. Denz, R. Filippini, R. Schmidt, J. Uythoven, M. Zerlauth and others (**ACTION: R.Schmidt**).

Handshake between PIC and QPS for powering electrical circuits - software interlocks (R. Denz & F. Bernard)
R. Denz and **F. Bernard** present the interlocking and QPS powering permit scheme, derived from status information of the local quench detectors, heater power supplies, etc.. (see slides for details).
For protection of the superconducting magnets, the Quench Protection System (QPS) and Powering Interlock Controller (PIC) emit hardware signals that may consecutively dump the beam and prevent further re-powering, in case of a magnet or circuit powering failure. The QPS issues a 'ST_CIRCUIT_OK’ (='ST_ABORT_PIC') signal that is hardwired through a current loop to the corresponding power converter and PIC. The PIC may eventually emit a beam dump dump request in case one of the involved systems (quench detectors, quench heater power supplies ...) is in a 'FALSE' state.
The software signal 'ST_PWR_PERMIT' is issued by the QPS on request by the PIC on a per circuit basis prior to the powering of a superconducting circuit. **R. Denz** points out that though a 'FALSE' state of this will prevent a power converter from powering up, a

'FALSE' state during operation will merely create an alarm seen by the operators in the control room. Typical failures that would cause a state change of this QPS signal during operation are failures of quench heater power supplies and may not necessarily compromise the function of the QPS. The quench heater power supplies, in case of the main dipole magnets for example, are 4 fold redundant whereas, depending on the magnet current, only about 1-2 would be required to protect the magnet. Quench heater power supplies have an estimated mean-time-between-failure of about 200 000 hours which make such failures very rare in the LHC. **R. Denz** notes that it is foreseen to test these power supplies once per month. However, if a powering subsector in the LHC operates for, say, some weeks, it cannot be excluded that failures accumulate. It is proposed that the LHC sequencer should check it the Quench Protection System is ready, for example before the start of the ramp or other machine phases to capture accumulating failures during multiple cycling of the machine. This needs to be included into the specification for the sequencer.
ACTION: M. Zerlauth.
F. Bernard presents the technical implementation on the PVSS supervision layer of the PIC and QPS that is used to retrieve the powering permit (see slides for more details).
In order to give a powering permit for a given circuit, the PIC supervision system requests the QPS permit status of the involved circuit through a defined CMW based data link. The retrieved information is time stamped inside the QPS. In case the response time or round-trip of the request exceeds about 5 seconds, the individual QPS state is considered to be 'FALSE' resulting in a 'FALSE' state for the total circuit powering permit. The detailed status of the individual QPS equipment (quench detectors, heater power supplies etc.) is available in the supervision system of the QPS.
The PIC surveillance application is implemented and being used in the ongoing hardware commissioning. The communication between the PIC and QPS surveillance system is presently under development.

AOB

Interlock of experimental magnets (J. Wenninger):
The four experiments use solenoids and spectrometer magnets inside the insertions. The spectrometers have relatively fast decay times in the order of seconds and must be interlocked. The coupling of the solenoid magnets is compensated with additional magnets in the vicinity of the experiments . In case of a power converter trip of a solenoid magnet, the magnetic field would decay with a time constant of about some hours leading to possible beam perturbations and potential particle loss. It is presently foreseen to interlock these magnets. However, CMS and ATLAS would prefer if the solenoids are not interlocked, but the MPWG recommends to foresee the hardware connections in any case, and to decide later if the interlock signals will be connected to the BIC or not.
ACTION: J. Wenninger

Minutes:
Newly available minutes will be announced as part of the invitation for the next meeting.
ACTION: R. Schmidt, J. Wenninger