Machine Protection Working Group

Minutes of the 46th meeting, held 1st July 2005

Present: F. Rodriguez Mateos, R. Steinhagen, R. Schmidt, J. Wenninger, V. Montabonnet, B. Goddard, V. Kain, M. Lamont, P. Pugnat, R. Denz, B. Puccio, R. Bailey, M. Zerlauth, C. Lallier, R. Filippini, B. Todd.

Meeting Agenda:

- Can LHC Orbit Feedback Correct for Closed Orbit Failures? [RST]
- Strategies for the Commissioning of the LHC Machine Protection System [RS]
- What Can Be Learned From LHC Hardware Commissioning? [FRM]

R. Schmidt began the meeting by saying comments on the Transfer Line Interlocking paper written by several members of the group are requested.

Can LHC Orbit Feedback Correct for Closed Orbit Failures? [RST]

R. Steinhagen made a presentation explaining the results of some studies carried out on the LHC Orbit Feedback System concerning compensation for Orbit Corrector Magnet (COD) failures. There are 1060 COD magnets in the LHC, studies were focused on the most common (752) superconducting MCBH/V magnets that are found in the arcs and are individually powered by ±8V/±60A Power Converters. Special insertion magnets were not considered.
R. Steinhagen summarised the MCBH/V circuit parameters used:

Inductance	*5.48H @ 120Hz*
Resistance	*65.4-91.3mΩ*
Maximum Deflection at 450 GeV/7 TeV	*1260 μrad /81 μrad*
Maximum. Orbit Shift at β~180 m	*144 mm / 9 mm*
Power Converter Maximum Slew	*$0.5As^{-1}$*
Maximum Orbit Shift Rate	*$1.2\ mms^{-1}$ @ 450 GeV*
	$75\mu ms^{-1}$ @ 7 TeV

The assumed worst case magnet misalignment of 0.4 mm rms (LHC target: 0.2 mm rms) corresponds to 8 μrad rms kicks onto the beam. This will be compensated in first order by the COD magnets.
R. Steinhagen showed that a COD failure becomes critical without control, as the beam orbit changes by an average of 0.9 mm (β~180) for each failure. This exceeds collimator tolerances by at least an order of magnitude. The Mean Time Between Failures (MTBF) of the Power Converters is expected to be around 10^5 hours giving a 7% chance of a MCBH/V COD failure during a single machine mission.
R. Schmidt noted that the accuracy of this figure is unknown, as the Power Converters used are a new design for LHC and have little information regarding their performance in a radiation environment.
R. Steinhagen agreed, saying the numbers were supplied by PO group, who were responsible for the Power Converter design. The natural decay time constant (τ=L/R) of a failing Power Converter - magnet circuit is around 140s. In case of a failure, the Power Converter circuit is shorted and slowly discharged through a 'crowbar' in order to prevent voltage / current spikes. The crowbar creates an additional series resistance of ~130 mΩ, reducing decay time to about 30s. Removing the crowbar yields a τ of 60-80s. **J. Wenninger** noted that the purpose of the crowbar was to decrease the decay

time so testing and commissioning of magnets could be carried out more quickly - exactly the opposite of the preferred effect for the stability of LHC orbit. **R. Schmidt** noted that for machine protection fast movements of the beam should be avoided if possible.
R. Steinhagen described a scheme using two neighbouring CODs to compensate the effect of a single failed COD, one to correct for the *kick* introduced, and another to adjust for the *phase*. Though only two magnets are sufficient for the compensation, spreading the compensation pattern over several magnets boosts the maximum slew/compensation rate. **R. Steinhagen** added that the same compensation scheme can be applied to the CODs in the dispersion suppressor regions. **R. Schmidt** noted that the orbit correctors outside of the arcs are already interlocked.
The proposed compensation is carried out by the foreseen Orbit Feedback Controller (OFC), a centralised unit calculating orbit corrections based upon signals from beam position monitors distributed around the LHC while accepting additional external feed-forward sources. The OFC should be aware that a COD has failed. The duration of the uncompensated decay of the failing COD field until the OFC is informed and starts acting, determines the ripple in the beam position. Notification time should be short to maintain a low ripple; an interval of 0.1s gives a ripple of 10^{-3}, whereas a maximum 1s interval gives a 3% ripple.

R. Steinhagen explained how this notification could be carried out either by:

1. *Direct trigger from the power converters indicating a circuit has failed*.
2. *Observing a beam drift indicating a failed COD*

The first solution is the quicker of the two. Presently the Power Converter status is passed without parsing from the Power Converter Gateway (PCG) to the OFC at a rate of up to 50 Hz. In the present design, the PCGs cannot give an asynchronous signal regarding the COD status. The PCG data needs to be parsed and verified to determine whether the power converter is still functional. Another fast-notify trigger approach would be to use the already implemented periodic real-time update at a rate of 50 Hz and to parse the COD status in the OFC. This would lead to ~30% higher network load in the OFC.

M. Lamont suggest work by **S. Page** had already been carried out to adjust the power converter gateways to generate a Post Mortem event on a Fast Power Abort, it could be feasible to add the required functionality.

Future Action: Investigate whether gateways could/should give an asynchronous COD failed signal [RST]

R. Steinhagen concluded that the LHC OFC *can* take actions to save the beam following a COD failure if an active link between Power Converter Gateways and OFC is present, and the OFC is notified within the first second of a Power Converter or COD failure. It was noted however, that the capture of these failures is not necessarily required for Machine Protection, but should increase the overall availability of beam in the machine.

J. Wenninger added that the Engineering Change Request for the removal of the additional crowbar circuits was under approval. **B. Goddard** then questioned the failure rate given for the PCs and whether more information could be presented to give a more general sense of the machine availability.
R. Schmidt said that this was outside of the scope of the Machine Protection Working Group.
R. Schmidt added that this system should be made available, despite its usefulness depending on the

MTBF of the Power Converters being correct, it was noted that the RSWG and HCWG require a substantial amount of time to have passed before any patterns of failures can be catalogued.
R. Steinhagen said that work of this nature was undertaken by PO group, giving failure rates and failure modes for the Power Converters.

Strategies for the Commissioning of LHC Machine Protection Systems [RS]

R. Schmidt then made an introduction to the topic of Machine Protection commissioning where several ideas exist about the way this should be undertaken. As the Hardware Commissioning Working Group has already overcome many issues related with such a task, it could be useful to use their work as a basis for a complete and robust commissioning of the LHC MPS.

What Can Be Learned From LHC Hardware Commissioning? [FRM]

F. Rodriguez-Mateos made a presentation showing the results of work that has been carried out over many months by the HCWG. Breaking down the key points into an overview, the documentation and the tools developed to facilitate Hardware Commissioning. The hardware being commissioned consists mainly of the superconducting and normal conducting electrical circuits, these have been broken down into smaller systems. **F. Rodriguez-Mateos** continued to describe commissioning beginning in the form of Individual System Tests (ISTs) that verify that each of the individual systems performs to specification after installation in the machine. **R. Schmidt** noted that the boundary of systems relevant to the Hardware Commissioning is clearly defined, with utility systems such as Electricity, Cooling and Water supply being considered as completely available.
F. Rodriguez-Mateos described how the emphasis was placed on paperwork with two types of documents needed for each system:

1. As Designed

- *Defines the prior state of the Equipment Under Test before the procedure (initial conditions)*
- *Defines the test Procedures, either step by step, or in a summary*
- *Defines the state of the Equipment Under Test after the procedure*

2. As Tested

- *A record of each and every systems performance with respect to the As Designed documents*
- *Including any anomalies and non-conformities*

To determine the commissioning procedures, over 50 meetings have been held, with around ten being held to discuss the actions to be taken in the event of a system failing the IST or another part of the hardware commissioning. Related equipments are arranged into Equipment Groups that will be tested together to verify inter-system functionality and to automate this process a series of Software Applications for the Commissioning of Electrical Circuits (SACEC) have been produced, an example being the sequencer that tests the PIC – QPS – PC links.
F. Rodriguez-Mateos continued, describing that the use of documents via a Document Plan is key to the complete commissioning of the LHC. The Document Plan uses EDMS and MTF tools as a basis giving a clear logical layout of the equipment in the machine either by location, or by function. It also gives a place to archive the technical documents for the ISTs, whilst giving a “real-time” process tracking of current operations and allowing quality assurance of LHC Hardware Commissioning.
R. Bailey questioned what happens in the event of a problem arising during the commissioning of a system, **F. Rodriguez-Mateos** replied that the Document Plan allows the timing of the HC to be

analysed, meaning any problems can be taken into consideration in the schedules. It was noted that controls are preferred to be available for tests to permit automation and easy supervision, and that an E-Logbook is maintained of the progress of the commissioning on a day to day basis, noting progress and problems.

Strategies for the Commissioning of LHC Machine Protection Systems Continued [RS]

R. Schmidt then presented some ideas and examples concluded from the key points of Hardware Commissioning that could be exploited for the commissioning of the LHC MPS. The LHC MPS Commissioning was divided into three sub-categories:

1. *Commissioning without Beam*
2. *Commissioning with Safe Beam intensity*
3. *Commissioning with Unsafe Beam intensity*

R. Schmidt continued to say that at each stage an IST would be performed, as well as a full Commissioning of the MPS before the next stage could be attempted. A similar document plan was proposed, with potential section members responsible for the actions along-side the machine protection systems that have to be commissioned.

Future Action: Build a Document Plan, and start working towards MPS Commissioning [ALL]

AOB

None

Next Meeting
TBC