SUMMARY OF SESSION 5
ELECTRICAL CIRCUIT RELATED PROTECTION

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Abstract

This paper summarizes the presentations and discussions during session 5 of the Machine Protection Workshop held on March 11-13th 2013 in Annecy. This session was dedicated to protection of the LHC magnet powering system and its related equipment and infrastructure. The following presentations were made:

- Powering issues (Scott Rowan)
- Changes in QPS (Reiner Denz)
- Changes in powering interlocks (Ivan Romera Ramirez)
- Electrical distribution: How to ensure depend- able and redundant powering of systems? (Vincent Chareyre)

POWERING ISSUES

Powering Systems

With almost half of the premature beam dumps originating in equipment systems related to the LHC magnet powering system, the powering system and dependability of associated protection systems will remain an area of particular importance for LHC machine protection. For power converters and interlock systems a reduction of premature beam dumps could be observed in 2012 with respect to previous years for all different phases of the operational cycle, confirming the effectiveness of mitigations and preventive maintenance performed during the past LHC run. At the same time the sensitivity of parts of the quench protection system to radiation effects was confirmed with a slight increase of dumps during stable beams (despite a first series of mitigations implemented). This was particularly visible for the QPS equipment in the caverns adjacent to the ATLAS and CMS experiments where radiation is mainly caused by the luminosity debris.

While the above is mostly a concern for availability, a few near misses have highlighted a certain vulnerability of the systems following human mistakes in operation/maintenance of the system or being caused by systems not being fully up-to-date. Examples are the non-openings of a main dipole energy extraction (EE) switch in sector 34 and of a 600 A EE switch in sector 12. The failures were due to erroneous interventions or due to the lack of detection of a quench caused by a stalled QPS controller. In view of these observations the following actions should be followed up:

- Revisit dependability studies including the relevant interfaces for the highest risk circuits (i.e. the main dipole circuits).
- Organization and follow-up of specific powering tests (CSCM, tests with nominal parameters…) to have an early assessment of potential limitations for post LS1 operation.

CHANGES IN QPS

While no major change of the protection functionality is considered necessary for post LS1 operation of the LHC, numerous consolidations (in the form of relocations and firmware upgrades) will take place to decrease the sensitivity of QPS equipment to radiation as well as to considerably enhance the supervision and diagnostic capabilities of the system. With almost the entire system being modified during LS1, emphasis has to be given to assure a full and thorough re-validation of the system at the end of the shutdown, including the verification of the related QPS instrumentation cabling.

Major upgrades of hardware and more importantly the firmware of the detection cards can presently only be smoothly implemented during the long shutdowns of the machine. This turned out to have a detrimental effect on the safety of the overall system as on some occasions mitigations in the form of a firmware upgrade could not be fully implemented during an operational year in the entire machine. This resulted in some of the near-misses described in the previous chapter.

Hence the following actions have been identified for detailed follow-up:

- Investigate possibilities for a remote download of firmware via QPS supervision.
- Based on enhanced diagnostic possibilities, implement additional mitigations to decrease the vulnerability of systems (e.g. additional sanity checks at start of each fill, dependable configuration tools, enhanced automated analysis, and enforcement of validations following changes).

CHANGES IN POWERING INTERLOCKS

The three interlock systems related to LHC magnet powering are triggering between one third and one half of the premature beam dumps and hence their performance is of particular importance for both machine safety and availability. The Fast Magnet Current Change Monitors have not been at the source of any spurious dump last year; however the particular sensitivity of the related thyristor power converters (namely RD1 and RD34) to electric network perturbations has been detrimental for machine availability. A full replacement of the power converter by a less sensitive type is currently not planned for LS1, but kept as a final means of mitigation. Current efforts focus on a collaboration with EPFL to improve the regulation characteristics of the converter, which,

according to the TE-EPC group allows for sufficient rejection of such perturbations.

A few dumps originating in trips of experiment magnets have highlighted the need to decrease the reaction time of the experiment Magnet Safety System (MSS) which will be done by replacing the current programmable FPGA cards by a NI cRIO FPGA based platform.

Likewise a few failures in the inner triplet circuits require follow-up to reduce interlock thresholds within the power converter and the removal of a watch-dog.

Following a recommendation of the Complex Safety Advisory Panels (CSAP), the powering interlock system will be extended to implement a hardware based link to the LHC Access system, replacing the current software implementation which has the task to limit the allowable current in LHC magnet circuits during special access conditions. The following actions will have to be followed up:

- Study improvements of converter regulation to improve rejection of network perturbations.
- Study cases of 'late' interlocks (EXP, 60APP and IT) and implement mitigations to restore redundant protection.
- Strategy for defining a certain circuit maskable/non-maskable/transparent for operation should be spread to all teams involved (OP, CRYO...) in order to apply this strategy coherently.

ELECTRICAL DISTRIBUTION: HOW TO ENSURE DEPENDABLE AND REDUNDANT POWERING OF SYSTEMS

In order to re-establish fully redundant powering for critical machine equipment, the UPS systems present in the LHC will be completely replaced by a new delta conversion model. This will allow redundant powering of the previously separated F3 and F4 lines, which – while powered from the alcoves - were not backed up by a second UPS and hence induced downtime in case of failure. The new delta conversion UPS systems in addition operate at different switching frequencies of 4 and 7 kHz (as opposed to the previous 7 kHz), imposing the following actions to be followed up:

- The new switching frequencies should be looked at in view of a possible implication on the tune measurement and damper systems.
- The extend of changes imply full-scale tests of the redundant powering of equipment related to machine protection (LBDS, BIS, QPS,…) which needs to be integrated into the LS1 planning.

APPENDIX – DISCUSSIONS

Powering Issues

R. Schmidt: What will we gain changing the parallel resistance (in order to avoid quench back)? **S. Rowan:** we will improve availability. **A. Verweij** commented on this: Such kind of change would be transparent for the magnet but the more quenches one can avoid the better for the magnet.

M. Zerlauth: What would be the feasibility of introducing an additional, direct link of the power converter with the EE system to increase diverse redundancy for its triggering? **S. Rowan:** Reiner's talk will address this in more detail.

Changes in QPS

E. Todesco: Will changing the thresholds for post LS1 operation mean mostly increasing them? **R. Denz:** It depends on the detector. Current lead detectors will have their thresholds lowered (from 3 mV to 1 mV), main dipole and quad will remain mainly unchanged while some IPQ's and 600 A (almost all of them) will have increased values accordingly to the type.

A. Siemko: What will be the situation for data acquisition of the Board B after LS1? **R. Denz:** After LS1 the operators and experts will have the possibility to access data from both monitoring boards simultaneously and retrieve both PM buffers (with some additional time delay).

M. Zerlauth: How to best mitigate human mistakes? **R. Denz:** More analysis tools that are integrated in the nominal cycle (e.g. the sequencer, PM analysis...) will have a large benefit. Not only after an event, but as well on long injection plateaus the consistency of signals can be checked. **R. Schmidt:** It is to be defined within the MP3 body how we go with mitigation of those human errors.

A. Verweij: Will timing corruptions (mainly inside PM files) still be an issue? **R. Denz:** No, due to massive firmware fixes and updates planned and performed during LS1 the situation is expected to be largely resolved, some single outliers cannot be excluded however.

Changes in Powering Interlocks

R. Schmidt: How to ensure that any masks (global subsector off, CRYO signals…) are removed when transiting from hardware commissioning into beam operation? **I. Romera:** The Beam Presence Flag is detected in the PIC SCADA system. If present, it could automatically disable any safety critical masking from the PIC supervision. **S. Claudet** proposed that the strategy for defining a circuit maskable/non-maskable/transparent for operation should be propagated to all teams involved in order to apply this strategy coherently.

M. Zerlauth commented on SPS renovation: With new hardware installed it will be possible to have some hard-ware interlocks for power converters & magnets instead of using SIS.

Electrical Distribution: How to ensure dependable and redundant powering of systems

G. Arduini: What will be the main switching frequency of the new UPS type? **V. Chareyre:** The two main modes will be 4 kHz and 7 kHz. **R. Steinhagen** asked if the

frequency can be adjusted in case of need as 4 kHz is close to the tune frequency? **V. Chareyre** answered that this is an internal UPS property and possibly can be adjusted within slight margins. **W. Hofle** added that the same issue needs to be verified for the transverse damper (ADT).

R. Schmidt: Can we identify equipment that is in sensible areas for LHC (according to slide 24? plot). **V. Chareyre:** Yes, action is taken and to be continued.

M. Zerlauth: The two Fast Magnet Current Monitors (FMCM) in IR1 and R5 are giving very different readings in case of global network perturbations, despite the fact they should be fed from the same 18 kV source (hence see the same perturbation in terms of duration and amplitude). Is this understood? **V. Chareyre:** Still needs to be investigated.