MACHINE PROTECTION WORKSHOP 2013
SUMMARY OF SESSION 1
MPS OPERATIONAL EXPERIENCE (2008-2012) AND OUTLOOK

T. Baer and D. Wollmann*, CERN, Geneva, Switzerland

Abstract

This paper summarizes the presentations and the discussions of session 1 - *MPS Operational Experience (2008 - 2012) and Outlook* - of the Machine Protection Workshop held from 11th to 13th March 2013 in Annecy, France. It gives an overview of the issues addressed in this session which need a follow-up. The four presentations made in session 1 are listed below:

- MPS issues and MP approach concerning operation and MDs (M. Zerlauth).
- Performance and availability of MPS 2008-2012 (B. Todd).
- OP view on handling of MP issues (G. Papotti).
- Global vision of MPS after LS1 and beyond (R. Schmidt).

MPS ISSUES AND MP APPROACH CONCERNING OPERATION AND MD

This presentation gave an overview of the major machine protection issues observed during the first running period (2010-2012). The handling of these issues was analysed from a machine protection expert viewpoint. Furthermore the handling of machine developments and other non-standard operation modes was critically reviewed and improvements for the future were proposed.

The main MP issues observed in the running period 2010-2012 are listed below:

- LHC Beam Dumping System (LBDS): common mode failure in 12V powering.
- Quench detection issues on IPQ and 600A Energy Extraction.
- HTS instrumentation cable on RB.A45.
- Wrong settings of transfer line collimators after the implementation of the new Q20 in SPS.
- Injecting timing issues due to test with high brightness beams in CERN-PS (H9).
- False collimator settings at the beginning of the 2012 run (TCTV 2x .IR2, 2x .IR3).
- Roman Pot Controls issues.
- BLM High Voltage Cable not connected.
- OFSU reference problems.
- BSRT Mirror degradation due to RF heating.
- MKI flashovers.
- QFB not usable in squeeze due to poor signal.
- Instrumentation problem in triplet L8 after TS2.
- Loss of redundant protection (60A power permits, LHCb dipole , CMS solenoid,).
- Tertiary collimators in IR2 not moving during squeeze.

Follow-ups

- Dependable tracking of relevant changes in MP systems.
- Assure more coherent approach for follow-up of magnet and beam related MPS issues (MPP, MP3).
- Define and enforce minimum validation of changes through the use of automatic tools and dependency models.
- Introduce the role of a Machine Protection Piquet to follow-up commissioning of machine protection systems, operational changes including the necessary revalidation, analysis and documentation of operational runs and beam dumps, as well as contact person (representing rMPP) to operations.
- Machine Developement: Mandatory note with detailed program and required changes to machine set-up needs to be prepared and approved for all MDs, to enhance safety and improve the efficient use of allocated beam time.
- The use of the three levels (normal, relaxed, very relaxed) of the setup beam flag (SFB) has not been very distinctively, i.e. in most cases either the normal or the very relaxed version has been applied (even during MDs). This needs to be reviewed and the use cases of the different levels need to be more clearly defined and re-enforced.

* daniel.wollmann@cern.ch

Discussion

- A. Siemko asks if there is an overlap between MPP and other working groups. Is there a need for reorganization? Any suggestions? M. Zerlauth replies that he does not think that any changes are needed. It works fine to discuss the aspects in different forums. The collaboration with the new MP3 panel will be intensified to guarantee a coherent approach for follow-up of magnet and beam related MPS issues.

- R. Jacobsson asks how the MP responsible would be integrated? M. Zerlauth replies that in certain situations fast reaction was needed and there is a certain conflict for the machine coordinator between luminosity production and MP. J. Uythoven comments that normally the EIC comes to the coordinator in case of issues. For the coordinator it would be useful to have a MP coordinator available to discuss. M. Zerlauth adds that there is a second facet: the follow up of MP issues. R. Jacobsson comments that this would be definitely a very good idea during MDs and commissioning. B. Goddard remarks that this would be helpful also during production runs.

- S. Redaelli mentions that there was not very much distinction between levels of safe intensities (Setup Beam Flag). R. Schmidt responds that we started 3 years ago very cautiously and gained more confidence with operation. But the large variety of levels is not transparent.

- D. Wollmann asks if the Acctesting framwork could be also a solution for revalidation after MDs, etc? M. Zerlauth responds that this will be addressed in K. Fuchsberger's presentation on Wednesday.

MACHINE PROTECTION SYSTEM: AVAILABILITY & PERFORMANCE 2010-2012

This presentation showed the results of an in depth study of the failures recorded in 2012 for the seven Machine Protection Systems and deduced recommendations following from this analysis.

More than 250 faults have been recorded in 2012 for these systems, with a total repair time of over 360 hours. With the help of an availability matrix the five most prominent failure modes have been identified: QPS: Radiation Induced Faults; QPS: Internal Communication Faults; QPS: Spurious Signal; BLM: Optical Link Failure - Surface; BLM: Optical Link Failure - Tunnel.

Follow-ups

- Changes in the different Machine Protection Systems should address prominent failure modes, as mentioned above, to improve the availability of the LHC.

- Planned changes to systems during LS1 should be studied to predict their influence on the availability of post-LS1 operation.

- A fault tracking system should be considered to improve data collection and analysis post - LS1.

- Post Mortem Events labelled as SIS should be further classified by the root cause.

- Infrequently activated inputs to interlock systems should be periodically tested to reduce the risk of dormant unsafe failures. About 50% of the BIS inputs never triggered since 2010.

- The origin of MPS abort events triggered by beam loss interlocks should be investigated to identify possible new hazard chains.

Discussion

- Dumps due to beam losses (BLMs):
  - R. Schmidt mentions that BLM dumps were often caused by losses e.g. during squeeze, etc. Any idea for other events, why and what could be done? B. Todd responds it would definitely be good to look in detail. J. Wenninger points out that many dumps occurred during the squeeze, due to instabilities, and those are very difficult to catch before by other detection mechanism.

- Post Mortem and improved fault tracking:
  - J. Wenninger mentions that PM comments from the EIC and MPS expert are typically very similar and could probably be merged. But some differentiations are needed.
  - S. Redaelli points out that problems in the shadow of other interventions need better tracking.
  - S. Redaelli states that very few cases of false dumps were caused by collimation.
  - A. MacPherson underlines that better fault tracking is needed.
  - W. Hofle asks if the goal of an improved fault tracking would be to increase availability or safety?
  - R. Schmidt points out that we can build available and reliable systems that improve safety without risking to loose availability.
  - B. Todd mentions that performance needs to be watched very closely, as from the number of false positives also the safety of the system can be inferred.
  - B. Goddard asks for the number of occurrences where a fill was not dumped despite a dangerous failure. B. Todd replies that he believes that this is zero.

OPERATION'S POINT OF VIEW ON HANDLING MACHINE PROTECTION ISSUES

This presentation focused on the operational experience with Machine Protection issues. Therefore, the major observed Machine Protection issues were classified into three categories:

- Failures that only experts can detect:
  - Common mode failure in LBDS 12V powering.
  - False settings of transfer line collimators, after shifting from Q20 to Q26 optics in the SPS.
  - Non connected BLM High Voltage Cable.
  - False collimator settings (2 x TCTV IR2, 2x IR3).
- Failures that shift crews can detect after a beam dump:
  - MKI flashovers.
  - Loss of redundant protection (60A power permits, LHCb dipole, CMS solenoid,).
  - Synchronization problem between SPS and LHC during injection (SPS in local).
  - Injecting timing issues in the SPS during tests with BCMS (Batch Compression, bunch Merging and Splittings) beams.
- Failures that shift crews can detect with beam stored in the machine:
  - RF feedback crate down, compromising the control of the whole RF line.
  - Beam Position Monitor readings unavailable during the ramp.
  - Tertiary Collimators in point 2 not moving during squeeze.
  - TCDQ not moving during the ramp.
  - Missing abort gap monitoring due to BSRT mirror failure.
- Dumps that could have been avoided:
  - Dump due to orbit excursion while setting up for 6σ Van der Meer scans at 1.38 GeV/c.
  - Dump due to wrong TCT settings, when exceeding the beam intensity limit defined by the Setup Beam Flag.
  - Dumps due to the weak instrumentation of the interlocked BPMs in IR6.

Follow-ups

- Implement software tools to help shift crew identify and notice the existance of unsafe machine states before the last dumps.
  - BLM reference/example readings for each beam mode.
- Revise Post Mortem (PM) analysis frame and possibly add missing PM checks (FMCM, PIC, BIC, IPOC). For example
  - Verification of collimation hierarchy.
  - Improve power loss module to identify losses higher than normal.
  - Revise Injection Quality Check as it currently latches too often, which weakens its protection functionality.
  - Revise LBDS XPOC checks to reduce the number of latches in non-critical modules (filling pattern, missing beam intensity and BLM data).
- Introduce a sequencer task to remove all masks during ramp down and preparation for injection. This will help to reduce the number of unnecessary dumps especially during Machine Development runs.
- Enforce thorough step-by-step procedures with lists of required setting changes and masks for special runs and MDs.
- Prepare more procedures to deal with possible failures, especially if they can avoid dumping the beam:
  - Orbit out of tolerance in point 6.
  - Increasing abort gap population well above the dump threshold: add values for the ADT to blow the beam out in a smooth and controlled way.
- Implement a training of shift crews on executing emergency procedures.

Discussion

- G. Arduini states that a better analysis of warning events would help (do not stress interlocks). G. Papotti refers to K. Fuchsberger's presentation.
- B. Dehning mentions that for the BLMs an automated failure detection is run about once per week. Also a tool for verification of loss profiles in the field of collimation is available (with need of optimization).
- M. Albert pointed out that the shift crew is not part of the machine protection system and has a significant reaction time.
- B. Goddard asks if there is a procedure for abort gap population. J. Uythoven responds there is a procedure in EDMS and thresholds are visible in an application which is running in the CCC.

- G. Papotti adds that often the problems are the details, e.g. in case of a not working dump, which ADT blow-up settings should be used?

- A. MacPherson proposes to add an EIC on rotation bases as member to rMPP.

- A. Siemko asks about wrong settings and if there exists an idea how these could be interlocked? G. Papotti responds that different hyper cycles are used e.g. for MDs, which include already a different set of settings including limits (collimators, power converters, etc). J. Wenninger adds that other systems like RF and ADT are not fully integrated into LSA and setting reversion relies on experts. G. Papotti comments that special runs have clearly been more critical concerning wrong settings. W. Hofle mentions that some of the settings are relying on certain information (like intensity going to be injected), which is currently not available with the required reliability.

- P. Baudrenghien asks if there is a redundant approach for abort gap monitoring foreseen for after LS1? J. Uythoven responds that there is a strong request to BI to make abort gap monitoring more reliable.

- S. Redaelli comments that the state machine was build e.g. to check for allowed actions, which would help for settings that depend on additional beam information.

- B. Dehning mentions that for the BLM system the settings are checked against values in the logging database. This approach could also be applied by other systems.

GLOBAL VISION OF MPS AFTER LS1 AND BEYOND

This presentation focused strongly on so called *catastrophic* failure scenarios like *beam deflected with non-nominal angle during a dump request* or *beam dump not working*. Their consequences were discussed in the view of recent simulations and damage experiments. Up to now their damage potential cannot be fully quantified, but the presented studies and experiments on hydrodynamic tunnelling should allow a better qualification of the expected damage in the future.

The second part of the presentation addressed possible new fast failure scenarios, which maybe introduced by future upgrades of the LHC (HL-LHC), like crab-cavities. Possible mitigation methods were qualitatively discussed.

Follow-ups

- Further study the consequences of so called *catastrophic* failure scenarios like *beam deflected with non-nominal angle during a dump request* or *beam dump not working*. In addition evaluate mitigation methods such as additional (wast-able) absorbers / internal beam dumps, redundant kickers with absorber blocks and check whether this could limit the potential damage to an acceptable level.

- HL-LHC: Study, if crab cavities will introduce a new type of very fast failures and investigate how to protect against these failures (LLRF, particle free gap between beam and collimators, ...).

- Study the impact of missing beam halo on the current protection strategy (redundancy, reaction time, etc.) and propose required changes.

- Study possible damage and collateral damage due to the use of non robust collimators in view of a possible gain in integrated luminosity.

Discussion

- B. Goddard points out that an internal beam dump would be very complicated and would imply a high redundancy of interlocking. R. Schmidt adds that additional kickers always would fire after the LBDS. But this needs to be evaluated.

- R. Bruce mentions, concerning the example of crab cavity failure, that the collimators will be at about 5.7 real beam sigma most likely after LS1.

- S. Redaelli asks if tests for some of the serious failure cases can be performed?

- A. MacPherson suggests concerning the fast failures in crab cavities, to look into mitigation methods on sub-turn level, like fast coupled feed-backs.

- P. Baudrenghien mentions that with 90deg phase change, the crab cavities could also be used for deflection.