SUMMARY OF SESSION 6 - OPERATIONAL ASPECTS

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Abstract

This paper summarizes session 6 of the Machine Protection Workshop dedicated to operational aspects related to Machine Protection.

The five presentations made in session 6 are:

- Post LS1 Operation (Gianluigi Arduini)
- Update on beam failure scenarios (Jan Uythoven)
- Post LS1 Operational Envelope & MPS implications (Matteo Solfaroli Camillocci)
- Software tools for MPS (Kajetan Fuchsberger)
- Interlock strategy versus availability (Laurette Ponce)

OPERATION AFTER LS1

Summary

In order to 'discover' the LHC at 6.5 TeV a short running period with 50 ns beams is desirable after a short scrubbing run. In this short period the pileup could be limited to around 40 events per crossing with a β* of 50 cm, close to nominal bunch intensity and low emittances (≈ 2 μm).

This initial period would be followed by an extended period of scrubbing (≈ 10 days) to prepare for operation at 25 ns. Operation with 25 ns beams would begin with a progressive intensity ramp up. Some form of β* levelling is very likely to be used in some IRs. For beam stability reasons it may be necessary to collide during the squeeze.

Other changes to LHC Run 1 standard operation involve lower (also higher) β* at injection and combined 'ramp and squeeze'. The baseline scenario must be defined in 2013 since we cannot implement all scenarios. The implications of the various scenarios and options for operation, collimation and machine protection should be studied.

The 25 ns and 50 ns BCMS beams (Batch Compression and Merging Scheme) are very attractive for machine performance but:

- the average energy density at 450 GeV for 50 ns and 25 ns beams is 35% and 70% higher than ultimate at injection,
- the average energy density at 6.5 TeV for 50 ns and 25 ns beams is 2% and 25% higher than ultimate at 7 TeV.

The consequences on the limits for the Setup Beam Flag (SBF) will have to be carefully evaluated.

The experience of 2012 shows that a working group that follows up on beam induced heating issues is required. Issues should be identified at an early stage to put in place countermeasures before damaging equipment. This beam-heating group could work in close collaboration to the Machine Protection Panel (MPP).

Discussion

F. Bordry: Should we scrub at an intermediate energy? **G. Arduini:** The higher the energy the more we profit from photoelectrons. An advantage to stay lower is the faster turnaround and possibly less UFOs. Nevertheless I propose to go directly up to 6.5 TeV because the aim is to condition the machine – unless we encounter problems. However, we have to be careful with the tuning of the ramp (cryogenic transients). The critical part is the start of the ramp.

R. Jacobsson: Do you expect any problems with heating of the TCTs? **S. Redaelli:** One TCP and two TCTs will be removed. So far only isolated issues have been observed.

R. Schmidt: Heating of components due to the impedance was traditionally not treated in MPP. Should this now also be made an MPP topic? It would be good to have a forum to address this. **J. Uythoven:** As long as issues arise on individual components the problem should be treated by the equipment owners, unless individual equipment failure may cause global machine damage, in which case it becomes a global MPS issue. **G. Arduini:** A follow-up to try to anticipate real problems is desirable, especially in view of higher beam intensity. Impedance related heating should be monitored continuously to avoid cases like the BSRT. **J. Wenninger:** There is some overlap with MPP but there are also other bodies who may address possible issues, but catching heating related problems at an early stage or at least being prepared at an early stage is crucial. **G. Arduini:** A weekly follow up on impedance issues as part of machine protection is necessary.

S. Redaelli: We should define a baseline (combined Ramp and Squeeze, β* levelling etc.) at some point because most of the things have important implications for example to controls, and not all possible paths can be implemented. **J. Wenninger:** It is planned to have a closer look at the different paths starting in April and discuss later in the year also with the experiments to weight all risks (complicated β* levelling may take weeks to be commissioned properly and in the end may not even be needed). A staged approach could be useful but it needs to be discussed.

G. Arduini: For going into collision already during the squeeze, we have to envisage a scenario to first close the primary collimators (to minimise the impedance) and then

the secondary collimators to avoid situations were all collimators move in at once. In 2012 collimators have been closed smoothly during the ramp. **J. Wenninger:** This could be done at a later stage. It is important though to prepare a combined Ramp and Squeeze and if it is proven to work efficiently and experience is gained with it, further steps to optimise it can be taken.

BEAM FAILURE SCENARIOS

Summary

All the 'Big Three' failure scenarios (powering failure of the D1 separation recombination dipole, injection kicker failure, asynchronous beam dump) occurred in the period 2009 – 2013, but with some modifications! Equipment weaknesses were detected for 2 out of 3 'Big Three' failure modes:

- The injection protection device TDI suffered from deformations due to heating by the beams,
- The LBDS had issues with the trigger synchronization unit TSU and with crate powering.

Unexpected failure scenarios occurred as expected. They were related to the timing system, beam heating, orbit bumps, UFOs, abort gap, quench protection. Improvements of our protection and additional surveillance had to be put in place rapidly in some cases.

The LHC MPS is relying more and more on SIS to cover subtle or across systems failures.

An important aspect of MPS after Long Shutdown 1 is to continue to understand each beam dump (post mortem) before continuing operation.

Discussion

E. Todesco: Why do you only quote the normal conducting D1 and not also the other super conducting? **J. Uythoven:** For the warm D1 the field decay is faster. Within a few turns one may get a significant change of the orbit. The SC-D1 reacts slower and the BLMs would have enough time to trigger.

S. Redaelli: Did you check if FMCM dumps could have been avoided? **M. Zerlauth:** I. Romera showed that all FMCM triggered dumps were justified, although there were situations where the associated converter didn't trip, but real current perturbations had been provoked, so there is nothing to gain. The only place where gains could be made is to apply modifications to the PC to improve the rejection of these current perturbations. TE-EPC is looking into this. First the PC regulation will be optimised and if that is not enough, then the converter would be exchanged.

R. Schmidt: It would make sense to quantify the SIL level of the FMCM although behind it there is still the redundancy of BLM and QPS. **J. Uythoven:** Even if it is not critical, it might still be interesting to investigate what the reliability of the FMCM is.

J. Wenninger: A test was already successfully performed to mask the D1-FMCM in order to see if the BLMs trigger correctly and demonstrate their protection role. **M. Zerlauth:** For the LHC the knowledge on the FMCM reliability is not so much an issue as there are 12 devices and therefore redundancy is guaranteed in case of a power cut; however, the FMCM exist also in the transfer lines where the redundancy is not existent. **J. Wenninger:** In the transfer lines there are, however, the current interlocks, which protect for drifts and trigger after a few ms.

SETUP BEAM FLAG

Post LS1 Operational Envelope & MPS implications

Summary

After LS1 the LHC will be operated at an energy close to 7 TeV. The value of the normal setup beam flag (SBF) would in this case allow an intensity of only one probe beam (10^{10} charges), which is likely to be a strong limitation for certain setup conditions.

The concept and limits for relaxed and very relaxed SBF must be reviewed, including the requirements for commissioning and MD needs as well as the risks.

Discussion

Ph. Baudrenghien: Off-momentum loss maps should not be considered as a big problem. Instead of moving the whole beam with a frequency trim one could selectively excite the synchrotron oscillation of single bunches. This could provide a much smoother measurement mechanism than what we have done so far. It should be looked at during LS1. **M. Solfaroli:** But this wouldn't remove the problem of beam dumps initiated by the interlocked BPMS in IR6. The beams would still be dumped. **J. Wenninger:** This opens up a protection issue as there is a frequency interlock because of the aperture of the dump channel. **B. Salvachua Ferrando:** It could be that we don't need to trim the frequency by 150Hz, probably less could be sufficient. We would need to perform tests at 7TeV.

M. Zerlauth: The situations when we use the safe beam flag need to be re-discussed, not only the levels and curves associated to its limits. The risk we take is not only related to the absolute values, but also the time spent in these modes. In the past the VERY RELAXED SFB sometimes has been misused (in MDs and other situations when it was not always necessary). Changing the limit curves will have an impact on the implementation side as the SMP is a very critical system. The question to SMP is at what point in time is it necessary to know the new values to make sure that the SMP is qualified to the level of dependencies we have today. **B. Todd:** A decision should be taken as early as possible. One should not forget that the SMP also controls the extraction from the SPS and that any change on the LHC side also affects the SPS extraction evaluations. A complete revalidation on the SPS extractions to LHC would be necessary.

R. Jacobsson: β^* levelling should be kept as flexible as possible (decoupling of IP1/5 from IP8)?

J. Wenninger: Limits for β* will have to be widened and levelling will only be performed in Stable Beam mode, with a smooth and transparent transition between the different values. A step by step commissioning for one IP or a group of IPs would be preferable to applying it to all IPs at the same time. β* levelling rations in IP1/5 will certainly be fixed.

SOFTWARE FOR RE-COMMISSIONING

Summary

There are currently new ideas and concepts to move the MPS commissioning and tracking information from the SharePoint WEB site to the ACCTEST software framework developed for Hardware Commissioning. In parallel the commissioning procedures must be updated to take into account the major changes that were applied between 2009 and 2013 to the actual procedures. The updated procedures must then be modelled in the ACCTEST database. Even without automating the tests, the ACCTEST framework could be used to track commissioning, take into account dependencies etc.

Finally it will be necessary to define projects and priorities for the aperture meter and online model.

Discussion

G. Kruk: Will operation continue to use the quite dangerous applications "EquipState" and "FESA Navigator" after LS1? **J. Wenninger:** The FESA navigator is usually not used except when there is no other application allowing communication with a new device. It is not evident to supress both applications from the CCC.

J. Uythoven: Concerning MPS tests with a new software tool, one should block on safe beam. **K. Fuchsberger:** The exact boundaries need to be defined by MPP.

R. Schmidt: After the development and usage of several generations of hardware control software tools we should ask ourselves of how to proceed with the next proposed tool. Should we define a new project? What are the next steps to proceed with it? **K. Fuchsberger:** The best would be that MPP answers these questions and takes them up to define the way to go. **M. Zerlauth:** The first part which should be defined and implemented is the sequencing of MPS tests together with a revision of the commissioning procedures, so that they could be fed into that new framework. The automation part of the steps could be treated then at a later stage. **K. Fuchsberger:** The majority of the work is done if there is a ported version of the current SharePoint site. **R. Schmidt**: A close collaboration between CO, OP and MP is absolutely necessary in order to define the boundary conditions for the advancement of this work. Questions concerning resources need to be addressed by the group leader. **V. Baggiolini:** The work done by Kajetan and CO in general is that the core package or framework is developed by CO experts in a way to allow system experts and/or other developers to provide plugins or modules to extend and complement that core system. This implies a close collaboration between CO and the individual system experts.

R. Jacobsson: We have repeatedly heard that there are many BIS inputs which have never pulled a beam abort and we said it would be necessary to verify that also those channels function correctly. Is there some sort of test-mode which would allow performing those BIS channel verifications? **J. Wenninger:** Yes, for some systems (PIC, WIC, BLM, vacuum) this exists, but it has not been followed up to extend it to all possible inputs. The concept is available and it could be envisaged to use it for all systems. A typical example of rarely used channels is the experiments. The injection permits are very often solicited but not the beam dump channels. **A. MacPherson:** During machine checkout a systematic verification of all input channels at the level of the BIS is performed. **S. Redaelli:** The proposal to automate MP checks is very good; however, it needs to be structured for commissioning. If we decide to change things, we need also to find the resources to implement them. We have many new projects coming up but not necessarily the manpower to do additional work, unless there is one central team which does the work and to whom specifications can be given for implementation. **K. Fuchsberger:** A first approach could be to include this into a sort of checklist and keep everything as it is now, so that no equipment tests would need to be modified, but at least an order in the execution of MPS tests is enforced. **A. Siemko:** There is definitely a need for improved software tools because this undoubtedly will improve the efficiency of many processes. A lot of good ideas have been presented (a sort of shopping list) and the next step should be to make a project proposal. Once we have this, we can discuss about resources, priorities etc. **J. Wenninger:** In the end we have to collect all ideas and decide amongst us which are the ones that deserve being followed up and possibly implemented. **J. Uythoven:** We should nevertheless keep in mind that a fast decision is necessary as the BIS commissioning will start in one year's time. If we miss this point, the project will be dead because people will be busy.

R. Jacobsson: When do you need the BIC inputs available from the experiments? **J. Wenninger:** Probably sometime during quarter-4 of 2014, when hardware commissioning will transit into machine checkout mode.

SIS AND/VERSUS BIS

Interlock strategy versus availability

Summary

The SIS is heavily used at LHC, with around 2700 subscriptions to equipment devices. While the SIS core is very reliable, it is of course sensitive to communication errors and network related issues. SIS was used to implement fast protection solutions to many problems that were discovered during operation.

The following points, that mainly concern the GUI and not the SIS core, could be improved after LS1:

- GUI layout,
- Post-mortem information,
- Parameter and value monitoring (including the subscription GUI),
- Masking.

The following interlocks could be moved from the SIS to the BIS in the future:

- The beam position interlocks at the TCSG collimator in IR6 and at the TCTs around the four experiments,
- The TDI gap interlocks.

The remaining orbit correctors interlocks that are implemented in SIS should be moved to the PC-interlock server written by K. Fuchsberger, while the beam position interlocks will remain inside SIS (for the start-up).

Based on the discussions during the workshop, one has to expect that new SIS interlocks will arrive after LS1.

Discussion

Ph. Baudrenghien: The FESA subscription problem is also critical for the RF and a degradation has been observed towards the end of the run. **L. Ponce:** This was also observed on the SIS. By looking at the timestamps of the SIS dumps, a concentration can be seen at the end of the run. **P. Charrue:** The problem has been identified as a problem in the interface of CORBA. A change is foreseen and hopefully by June 2013 we will have a new version and all related problems should disappear. Tests will of course be needed to validate it.

R. Jacobsson: The interlocks can be divided into two classes, on one side the consistency checks with hardware interlocks securing the machine and on the other side the time critical interlocks. For the latter I've always been puzzled that the general network, which doesn't allow for priority treatment of packages, is used to communicate. **R. Steinhagen:** The current infrastructure doesn't support ways to split servers providing general purpose information on one network and specialised information for particular clients on another network. **J. Wenninger:** It's mostly a problem with servers and not so much with the network itself. On the outgoing side of the SIS everything worked fine. A beam dump is initiated if the BIS doesn't receive the SIS data within a 20s timeout, however, this never happened. This confirms that the network worked fine. The problem was rather observed on the incoming side, which includes servers publishing their respective data.

Ph. Baudrenghien: The increased SIS timeout could be reduced again once the new CORBA version will have been successfully deployed. **J. Wenninger:** Yes, we should try to reduce the timeout again to its initial value.

V. Baggiolini: As the SIS proved to be very reliable over the past, is there any place where you are abusing this reliability when software is used as a last line of defence for machine protection. **J. Wenninger:** Maybe we could formulate it differently. Because of SIS working so well, there is no strong pressure to move interlocks from SIS to BIS. So in some sense you're partly right. **J. Uythoven:** Systems which are safety critical should not go into SIS, even though at first glance it looks very reliable.

L. Ponce: Probably the BLM-HV interlock as a rather safety critical interlock should be moved out of SIS and be implemented as a hardware interlock. All the other SIS interlocks form more an extra layer to prevent a system failure. **E. Holzer:** The BLM-HV SIS interlock was added to protect from the fact that a cable was cut. Before a fill, the cabling is checked as part of the BLM sanity checks but after that, there is no monitoring anymore. This was the reason to introduce the interlock.

B. Goddard: The 'beam position at TCDQ' interlock could be implemented in hardware as well. **J. Wenninger:** We have at least the beam position at the TCSG as hardware interlock. **R. Steinhagen:** It will be difficult to implement it as hardware interlock as it can't be done by surveillance of a single BPM neither by monitoring a single PC. It's a protection against closed orbit bumps for which one needs combined information.

J. Wenninger: In principle the BLMs provide the ultimate protection. It's just a way to avoid stressing systems unnecessarily. **J. Uythoven:** The BLM-HV interlock should be implemented as HW interlock.