SESSION 8: WHAT WE WILL DO FOR BEAM PREPARATION IN 2009 - SUMMARY

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AIM OF THE SESSION

The sector 3-4 incident and the experience gained in 2008 during Hardware Commissioning, Dry Runs, Machine Check-Out and Beam Commissioning have evidenced the need for a series of modifications in the hardware and in the procedures to commission it.

As in 2008 a careful preparation of the machine for beam commissioning is crucial for a successful start-up with beam. The aim of the session was to review:

- the activities that could not be completed in 2008 that need to be performed in 2009,
- the planned modifications and impact on the re-commissioning of the systems,
- the new procedures for the commissioning as a function of Sector 34 incident,
- the tools to speed-up the re-commissioning,
- the impact of new access rules on "sectorized" cold check-out in parallel to HW Commissioning,
- needs and possible strategy for training of the SC circuits for 5 TeV operation or higher

in order to prepare the Dry Runs and the Machine Check-Out.

The Session consisted of six presentations:

- Magnet circuits (A.Vergara)
- Powering interlocks (M. Zerlauth)
- Beam interlocks (J. Wenninger)
- Injection and Beam Dump (J. Uythoven)
- RF (E. Ciapala)
- SC magnet (re)training (E. Todesco)

MAGNET CIRCUITS

A. Vergara gave a brief overview of the commissioning of the superconducting circuits performed in 2008 and the lessons learned from that experience. The status of the commissioning of the LHC Sectors on 19th September 2008 (with the exception of Sector 34) and the known non-conformities are being summarized in EDMS documents to be released soon [1]. In 2009 the status of the circuits will differ according to the interventions that will be performed in each of them. Three classes of circuits can be schematically identified:

- circuits warmed-up and modified (e.g. circuits opened in Sector 3-4)
- circuits warmed-up but not modified (e.g. dispersion suppressor quadrupoles in Sector 5-6)
- circuits kept cold (e.g. circuits in Sectors 7-8 and 8-1)

The extent and type of tests to be performed will therefore depend on the history of the circuit. The procedures for each of the three commissioning scenarios have to be reviewed to account for the modifications to the Machine Protection system and for the lessons learned from the Sector 3-4 incident. A review of the parameters required for operation (e.g. current ramp rate and acceleration) is also required before starting the tests in order to apply commissioning parameters compatible with the operational needs.

Commissioning to energies lower or equal than 5 TeV it is not expected to allow saving powering time but the commissioning of the main circuits to an intermediate energy (e.g. 4 TeV) could allow gaining operational experience before increasing the energy to 5 TeV while minimizing risks.

The 2008 Commissioning has shown that parallelism is possible but in practice progress in the tests will be strongly conditioned by the access procedures during powering. These are likely to be changed as a result of the Sector 3-4 incident as compared to those in force before 19th September.

Most of the powering tests take place at low current and therefore more flexibility could be achieved by allowing restricted access when powering is occurring at currents below a given limit applied hardware-wise on the power converters.

The review of the access conditions during powering is ongoing and the results of that are needed to finalize the strategy for the commissioning.

The development of tools for showing on-line powering condition vs. access conditions are mandatory in order to help the commissioning teams in the management of the safety during commissioning.

The possibility of running nights and week-ends has been evoked as a possible mean of minimizing interferences between powering tests and work in the tunnel but it is not clear whether enough experts would be available for guaranteeing sufficient coverage even more considering that many people involved in Hardware Commissioning have left since 2008.

POWERING INTERLOCKS

M. Zerlauth gave an overview of the modifications being implemented in the powering interlocks that protect the normal conducting (Warm magnet Interlock Controller - WIC) and superconducting magnets (Powering Interlock Controller - PIC) e.g. in case of a quench in a superconducting circuit or in case of over-temperature in a normal conducting circuit. He also reviewed the work ongoing on the Fast Magnet Current change Monitors (FMCM) which detect any fast current decay in warm magnets and trigger a beam abort to prevent damage to equipment.

The installation of the FMCM (12 circuits) is being completed (one -unused- circuit was missing on 19th September), the control interface is being completed and the settings for these monitors will have to be adjusted for full operational range (injection to nominal).

A redundant channel with faster reaction time is going to be activated for the Warm Magnet Interlock Controller (45 circuits) as required for operation with unsafe beams.

Both FMCM and WIC will have to be fully re-commissioned. Given the limited number of circuits and the limited time required for the commissioning of a circuit no automatic procedure will be available for 2009 (but later).

No modification of the hardware is planned for the Powering Interlock Controller protecting the superconducting circuits (820 circuits + 752 - 60 A orbit correctors) but the QPS system, one of the client of the PIC is undergoing important modifications. Except for Sector 34 (to be considered a new sector) the hardware commissioning steps for verifying the powering interlocks need to be repeated. An automatic procedure is being put in place (except for main circuits) in order to speed up these tests, moreover automatic tests procedures for the verification of the PIC to Beam Interlock Controller (BIC) connection are available as well.

M. Zerlauth concluded mentioning that a failure of the CPLD XC95144 used in the PIC has been observed during recent tests performed in the CNGS radiation test facility although it is not yet clear whether this is due to radiation.

BEAM INTERLOCKS

The LHC is equipped with a large Beam Interlock System with approximately 10000 devices/interlocks connected to Beam Interlock Controllers (BIC) and about 3800 Software Interlocks.

A blind failure resulting from the coincidence of five events was detected during the LHC cold check-out. A solution was in place for the start-up with beam on 10th September and definitive changes and measures are being implemented during the shut-down.

The Safe Beam Flag distribution in the LHC was available but it could not be fully commissioned as the machine was operated only with probe beam.

J. Wenninger highlighted that a full test of all the Beam Interlock System (BIS) will be needed again in 2009. In order to do that automation is a must: this has started in 2008 (e.g. PIC-BIC connection) and it is being extended in 2009. The documentation effort started in 2008 is being completed with the finalization of the procedures for the machine protection commissioning. The progress of the tests in 2008 has been documented in the form of Excel spreadsheets. In 2009 MTF will be used for that.

One of the largest and most critical clients of the Beam Interlock System is the Beam Loss Monitoring system. This will have to be thoroughly tested with particular emphasis on the reliability aspects. Preliminary tests in 2008 have allowed identifying some noisy channels which have been repaired. Almost half of the Beam Loss Monitors will be dismounted during the shut-down and for that reason all the channels will have to be tested again with a radioactive source.

The post-mortem system was only partly available and tested in 2008. In 2009 the system will have to be extended and it will be needed in the analysis of the tests of the Machine Protection System, of the programmed dumps and of the emergency dumps that will naturally occur during the run.

Based on the 2008 experience a staged commissioning of the Machine Protection System (MPS) is being envisaged to provide some flexibility for safe MPS and beam commissioning in parallel. For each step the corresponding parameter space (intensity, energy and emittance) envelope for safe operation has been identified. Whenever the machine is operated outside the explored and tested envelope (e.g. when optics, energy are changed) the probe beam should be used.

In order to create the conditions for safe and efficient operation with pilot beam few days with machine closed and operational will be needed to commission the Beam Dump System and the Beam Interlock System.

A team of Machine Protection Experts should trigger and follow-up the staged Machine Protection System commissioning and to support Machine Coordinators and Engineers in Charge in the definition of the possible envelope for operation in case of abnormal operation of any BIS element.

INJECTION AND BEAM DUMP

J. Uythoven presented the list of modifications being implemented on the Injection and Beam Dump systems as a result of the observations conducted during dry runs and machine check-out in 2008:

- One injection kicker magnet in LSS2L will be replaced by a spare after it showed a breakdown that could be the consequence of an over-voltage during the conditioning in the laboratory.
- Additional beam loss monitors will be added to protect the injection kicker against flashovers that have been possibly observed as a result of beam losses during aperture studies. An improved conditioning sequence (called SoftStart) will be implemented as well.
- Injection absorbers (TDI) and TI8 transfer line collimators (TCDI) are being "consolidated" and will have to be re-commissioned.
- The injection magnetic septa (MSI) should be run in DC mode during injection and they should be ramped down slowly at the end of the injection process so to minimize the closed orbit distortion observed during the beam commissioning very likely due to the effect of the stray fields of these magnets on the circulating beam.
- The MKD generator temperature will be regulated and an interlock on it at $\pm 1^0$C will be implemented to avoid any drift in the strength of the beam dump

extraction kickers MKD. A dependence of the strength on the tunnel temperature (~ -0.2%/^{0}C) has been in fact observed in 2008. Thorough tests will have to be performed to qualify this modification and to gain operational experience to prevent any loss in reliability of this critical system.

- The Beam Dump Dilution Kickers (MKB) have been consolidated to minimize the risk of flashovers observed in 2008 A reduction of the vacuum conductance between tanks and an increase of the pumping speed should also avoid common mode failures observed during the past run as a result of vacuum deterioration in one tank and cross-talk to others.
- In 2009 the MKBH installation will become nominal and 4 out of 6 MKBV magnets will be installed.
- Additional redundancy will be added for the verification of the position of TCDQ collimator (protecting Q4 and the arc in case of asynchronous dump) by introducing an 'independent' check as a function of the beam energy (now only triggered via timing).

Given the number of modifications being implemented a thorough test of the injection and beam dump system is required. A Beam Dump Reliability run over more than 4 weeks effective running is needed in order to collect enough statistics for possible failures.

As part of the Machine Protection commissioning the tracking within tolerance of the voltage of the beam dump system with the machine energy must be tested before beam injection. The tracking tests require the availability of the main bends in 4 sectors (45/56/67/78).

RF

E. Ciapala summarized the status of the RF and Transverse damper commissioning on 19th September. Some of the Beam Controls systems could not be tested with beam before that date. In particular the beam control for the RF synchronization, capture and transverse damping could be tested only for beam 2 while collision, acceleration and radial loop could not be tested at all. No damage was observed on the RF systems as a result of the Sector 3-4 incident but a similar event, close to IP4, with sector valves open would result in dust contamination or even mechanical damage, for that reason vacuum vales should be kept closed during powering tests without beam. The installation of fast sector valves was also evoked during the presentation but it is not clear whether this solution could provide a sufficient protection for the RF cavities in case of vacuum incidents occurring in the long straight section. Furthermore the installation of such valves could introduce an additional risk that the beam might not be dumped before the valves close with severe consequences for the cavities.

A weakness in the tuning system of the RF cavities has been detected during the cavity operation in 2008 and it is being repaired

Powering tests of the acceleration and transverse damping system are required and the RF cavities will have to be conditioned. E. Ciapala reminded that access restrictions in UX45 can slow down this process. The definition of the access procedures is therefore urgent to define the impact on the planning.

The situation of the spares for the RF cavities is worrying. A proposal to purchase 3 more spare cavities and the Helium tanks (~300 kCHF), whilst companies have still the know-how to produce these components, was made.

MAGNET (RE)TRAINING

E. Todesco presented the results of a study to determine the requirements in terms of training of all the LHC superconducting magnets as a function of the energy of the machine. The analysis is based on the data collected in SM18 and during the Hardware Commissioning for all the magnet types. For the dipoles a Monte-Carlo simulation of the training has been built based on the above data. The comparison of the model with the results of the training campaign conducted in Sector 56 provides a good agreement up to 6.3 TeV equivalent current. The number of training quenches estimated from the model is dominated by those needed for the training of the dipoles and can be summarized as follows:

- for 5.5 TeV: a few (<5) quenches over all the machine;
- for 6.0 TeV: ~15 main dipole quenches, 5 insertion quadrupole quenches and 5 separation dipoles quenches;
- for 6.5 TeV: ~80 main dipole quenches, 5 main quadrupole quenches, 15 insertion quadrupole quenches, and 10 separation dipole quenches.

At present it is difficult to give a realistic estimate on the number of training quenches required to get to 7 TeV before having the experience of at least one octant.

CONCLUSIONS

A large number of modifications are being implemented on top of those resulting from the Sector 3-4 incident as a result of the experience collected during in 2008.

The documentation effort conducted so far and the review allowed identifying the work to be done and the requirements for the preparation of the Dry Runs and Machine Check-Out.

For the superconducting circuits the following issues need to be addressed urgently:

- procedures for powering safely taking into account the modifications of the magnet protection systems;
- definition of access conditions during powering

these activities have already started.

One of the critical elements of the LHC machine is the Machine Protection System. The steps for its staged commissioning have been sketched. The initial phase includes a period of a few days with machine closed and operational before establishing circulating beam.

Although the experience gained in 2008 and the documentation work provide a good basis for the commissioning in 2009, updating of the procedures and test automation are essential in order to compensate for the reduction in resources occurred at the end of 2008 as a result of the departure of several members of the Hardware Commissioning team.

A review of the spare policy is recommended after the 2008 experience, as an example the number of spare RF cavities should be increased.

ACKNOWLEDGEMENTS

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REFERENCES

[1] Boris Bellesia, Carlos Fernández Robles, Mirko Pojer, Matteo Solfaroli Camillocci, Antonio Vergara Fernandez, LHC-MPP-HCP-0078, LHC-MPP-HCP-0079, LHC-MPP-HCP-0080, LHC-MPP-HCP-0081, LHC-MPP-HCP-0082, LHC-MPP-HCP-0083, LHC-MPP-HCP-0084.