WHAT WILL WE DO FOR BEAM PREPARATION IN 2009: INJECTION AND BEAM DUMP

J. Uythoven, CERN, Geneva, Switzerland.

Abstract

The hardware changes and maintenance actions on the LHC injection and beam dumping systems are presented. The requirements for equipment tests, hardware commissioning and machine check-out will be given, highlighting the dependence and the impact on other interfaced LHC equipment.

INTRODUCTION

During the 2008 operation with beam, the LHC transfer lines, injection and beam dumping systems performed without any major complications [1, 2]. Lessons were learned from the operational experience, either with or without beam, and modifications to the different systems are foreseen to be applied for 2009 operation. These changes are presented for the transfer lines, the injection system, the kickers of the beam dumping system MKD and MKB and their controls.

For these systems the requirements for the commissioning without beam are detailed, paying particular attention to the interfaces to other equipment.

LHC TRANSFER LINES

Transfer Line Modifications

Following the investigations on the measured dispersion in TI 8 [2], the Beam Position Monitors in this transfer line will be upgraded to read in both planes and four additional BPMs towards the end of the line will be installed. Similar modifications to the TI 2 BPM system are foreseen to be installed in the following shutdown (2010 – 2011).

A full alignment campaign for both the TI 2 and TI 8 transfer lines has taken place, which should ease and improve the performance of the lines. The control systems of the power convertors on both transfer lines have been moved to FESA.

During operation with beam it was noticed that periodic orbit distortions of both beams were measured, with the same period as the pulsing of the transfer line. The most likely source of the orbit distortion is the stray field of the LHC injection septa MSI. It is foreseen to operate the MSI in 2009 in DC mode during the injection phase.

The transfer line collimators TCDI in TI 8 have shown problems with screws and springs on the roller cages. The TCDIs installed in the transfer line tunnel will be repaired before the end of March (SPS shutdown), the ones in the LHC tunnel will also be repaired, depending on when LHC access to LSS8 is possible.

Transfer Lines Commissioning without Beam

The modifications to the TI 8 BPMs will need to commissioned and integrated in LSA, YASP and the logging.

The operation of the power converters under FESA will need to be commissioned and checks will need to be made concerning the logging. The operation of the MSI in DC mode and the method of ramping it down at the end of the injection phase will need to be tested.

The modified transfer line collimators will need to be tested and calibrated. The calibration can be done remotely without tunnel access.

The hardware commissioning of the transfer lines should take place during the SPS cold checkout. Beam tests up to the upstream TEDs (TT40 and TT60) should take place in May, beam tests up to the downstream TEDs should take place in June. For the tests up to the downstream TED, the corresponding two LHC sectors and the experimental area will need to be closed and access will only be possible after a radiation survey.

INJECTION SYSTEMS

Injection System Modifications

The injection kickers MKI operated correctly with beam. The kickers are delicate equipment, operating near the limits of the technical possibilities, due to partly conflicting design requirements like kick strength, rise time, flat-top ripple, aperture, beam impedance and vacuum.

The MKI magnet D installed in LSS2L will be replaced by the spare magnet. This magnet had shown a breakdown, as it was weakened probably due to an over-voltage during the conditioning in the laboratory caused by a calibration error. The assembly of a second spare MKI magnet should be finished by the third quarter of 2009.

There are indications of MKI flashovers being triggered by beam losses during the aperture studies. This could become an issue for even relatively small beam losses during operation with higher beam intensities. To be able to better quantify the beam losses in the kicker area, the temporarily installed Beam Loss Monitors have now been definitively positioned between the MKI's D/C and C/B, to monitor the beam losses. They will initially only be used for diagnostics, possibilities of interlocking operation because of (accumulated) losses measured will need to be studied.

Drops in conditioning of the MKI magnets have been noticed after extended periods without pulsing. This can lead to a break-down in the magnet at the first injection after a pause. During 2008 operation a 'SoftStart' has

been applied, which verified if the magnets were still properly conditioned before operation at nominal voltage, if the magnets had not been operational for more than 60 - 90 minutes. The 30 minutes SoftStart in 2008 could be launched by the sequencer, in parallel with other preparation activities.

For 2009 the SoftStart will be modified to have more configuration parameters, like a faster voltage ramp-up at lower voltages and the variation of pulse length. All SoftStart parameters will be under RBAC and only an equipment specialist will be able to change them. Due to the increased flexibility the modified SoftStart is expected to take about 1/3 of the present time. It should be noted that the new SoftStart depends on RBAC, LSA and the timing system and can only be used with a machine in 'operational mode'. The normal conditioning of the magnets should continue to be done in local mode.

Other changes to the injection system are:

- Remote reset of a magnet vacuum interlock by the equipment expert.
- Remote access to the local oscilloscope for improved diagnostics during operation.
- Modification to the MKI thyratron bias boards to reduce the number of erratics.
- Fully redundant connection to the injection BIC.
- Tri-axial cables for transmission of the signal of the transfer line BCT, used for the MKI synchronisation with OASIS.
- The TDI absorbers have shown leaky seals on the motorisation. The TDI in LSS2L is presently removed and will be back by the beginning of March, the one in LSS8R will be removed when there is access to the zone, but is expected to be reinstalled in April.

Injection System Commissioning without Beam

Main items to be re-commissioned for the LHC injection system are the replaced kicker magnet in LSS2 and the new SoftStart system. The replaced TDIs will need to be tested and calibrated.

The commissioning of the MKI control system should start by the end of February for LSS8 and in March for the system in LSS2. By the end of March remote operation of the system in LSS8 should be possible, in April for LSS2. From the end of March onwards regular dry runs will need to be organised to coordinate the remote operation from the control room. During the dry runs the interface to many other systems will need to be tested: timing system, beam instrumentation, injection sequencer and logging system.

BEAM DUMPING SYSTEMS

Beam Dumping System Modifications

Additional dilution kicker systems MKB will be installed for 2009 operation. The horizontal dilution system will have the nominal 4 magnets per beam (2 tanks per beam). The vertical dilution system will also have 4 magnets per beam, which is 4 / 6 of the nominal system.

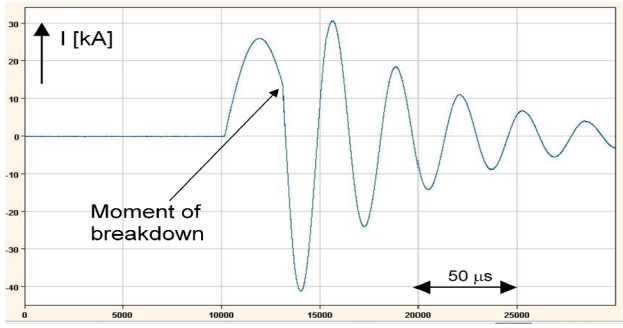

Figure 1: Measured MKB magnet current at the moment of a flashover.

During the 2008 commissioning period flashovers occurred in the MKB magnets of the beam 2 system, due to a bad vacuum which was not properly interlocked, see Fig. 1. This event identified weak insulators which will be replaced on all systems. The coils of the magnets with a break-down will also be replaced. This event also showed a dangerous common mode failure which was not realised before. To avoid the pressure wave in one tank causing the onset of a breakdown in an adjacent tank, the conductance between the MKB vacuum tanks will be reduced. Additionally, extra turbo pumps will be installed on the MKB systems to reduce the pump down time.

On the beam dumping system extraction kickers MKD a temperature effect on the solid state switches in the generators was discovered during the reliability run which took place from November 2007 onwards [3], see Fig 2. The temperature increase can be due either to a change in the global air temperature in the UA, or to the internal heating of the MKD generators, when the are maintaining their full voltage while sitting a 7 TeV settings, see Fig. 3.

The obtain the required MKD kicker kick strength stability, a Peltier cooling system will be installed on each of the 30 MKD generators, together with temperature isolation and a ventilation system. The proposed regulation temperature will be the standard tunnel temperature of 23 degrees, interlocked at ± 1 degree. A humidity sensor with an interlock will also be installed. An interlock to either temperature or humidity will result in a synchronous beam dump. A restart of the system will only be possible when the correct conditions are back.

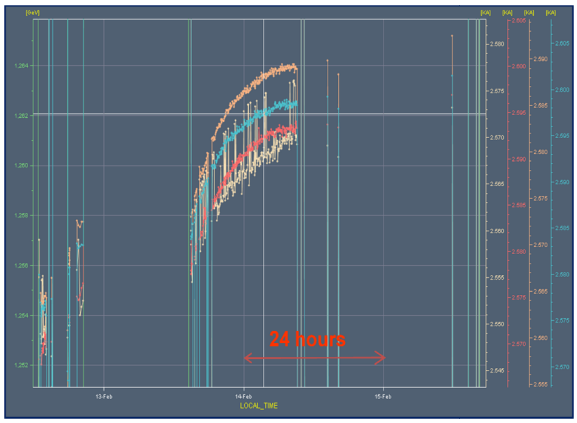

Figure 2: Increase of MKD kick strength by about 0.8 % during period in which the UA temperature increased by 4 degrees.

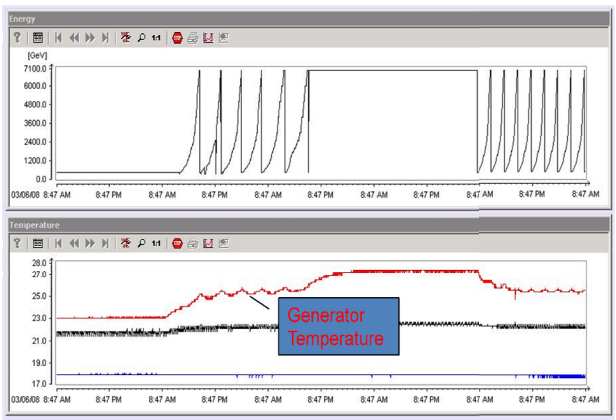

Figure 3: Top graph showing the energy setting of the MKD generators and bottom graph showing the measured MKD generator temperature for the same period..

Other changes to the beam dumping system foreseen for 2009 operation are:

- The second MKD current measurement, based on Rogowski coils, will be used with realistic limits for both the Internal Post Operational Check (IPOC) and the External Post Operational Check (XPOC).
- A fast detection system of mains and UPS instabilities will be installed at the level of the Trigger Synchronisation Unit (TSU). It will be directly connected to the re-trigger lines and will cause an asynchronous beam dump for t > 75 ms. This is on top of an existing detection system at a higher level which triggers a synchronous beam dump for t > 60 ms.
- The TCDQ system will have an independent check on its position taking the beam energy as independent input parameter. This will reduce its sensitivity to errors related to the timing system. If an error is detected, a synchronous beam dump will be triggered.

Beam Dumping System Commissioning without Beam

The Reliability Run [3] as done in 2007 – 2008 produced sufficient data for 'equipment statistics', however 2009 will need at least four weeks of effective system running time to obtain operational experience and failure statistics after the system modifications. Well organised dry runs for testing the interface to other equipment are mandatory for a smooth start of the operation with beam.

Particular attention will need to be paid to the preparation of the External Operation Check system (XPOC). During 2008 the MKD and MKB kicker waveform check was already fully operational and worked correctly [4]. For 2009 operation with beam the XPOC check will need to be extended to the following systems:

- Analysis of the beam losses by the BLM system.
- Current measurement in the TD line from the FBCT, compared to the stored and injected beam currents just before the beam dump.
- Abort gap monitor signal.
- Detailed analysis of the BTVDD image.
- Analysis of the BPM signal in the TD line.

The last two items above depend on the filling pattern which will need to be taken into account. Again careful commissioning of the beam instrumentation required for the XPOC system during dry runs will be obligatory.

The commissioning of the beam dumping system can be separated in three periods:

1. Equipment 'controls' commissioning

The MKD generators have been fully de-cabled for the installation of the cooling and need full re-testing. The new MKB generators will need to be tested and commissioned. High Voltage is required from the beginning of these tests. During all tests the MKD and MKB systems belonging to the same beam will be commissioned together.

2. Local operation under High Voltage

Operation of the kicker system up to full energy settings is checked (this will be 7 TeV, even if the maximum beam energy foreseen 2009 – 2010 is likely to be 5 TeV). The energy reference will be locally generated. Calibration tables will be made, used for the generation of kicker settings and IPOC / XPOC references and limits.

3. Remote operation from the CCC

The energy reference during this period can either be the BETSsim, simulation program for the generation of the energy reference, or come from the Main Bends of the adjacent octants (can be staged from 1 – 4 octants). During this phase the energy used will be distributed by the timing system as part of the Safe Machine Parameters, so it can be used by other system (BLMs, collimators). Coordination for the use of the transmitted energy will be required.

During this phase additional dry runs will be required to test the interface to many systems. A new arming

system for the Beam Interlock Controller (BIC) will need to be tested. Once connected to the BIC, many systems will need to be masked to be able to close the BIS-loop. It is foreseen to alternate 'masked' and 'unmasked' periods of two weeks. The access system, which has a direct entry point into the beam dumping system, will need to be masked at the access system level. Additionally, the interfaces to the following systems will need to be tested:

- The timing system.
- The RF-system for synchronisation.
- The Q4 and MSD for energy tracking.
- The XPOC, LSA, MCS and RBAC systems.
- Abort gap monitoring system.
- The injection systems.

CONCLUSIONS

The Beam Position Monitoring system of the LHC transfer line TI 8 will be upgraded for 2009 operation. Both transfer lines will have been completely realigned. The transfer lines will need to be re-commissioned with beam well before the first beam into the LHC is planned. For beam tests up to the downstream TEDs the adjacent LHC sectors and the experiments will need to be closed.

One injection kicker MKI is replaced in LSS2. Additional BLMs at the kickers are now definitely positioned and a new SoftStart of the kickers will be in place and will need to be commissioned. The TDI absorbers and the TCDI collimators in the transfer lines will be repaired and will need to be commissioned after re-installation.

On the beam dumping system the number of dilution kickers for 2009 operation will be doubled. Cooling (and interlocks!) is added to all 30 MKD generators. The commissioning time of the beam dumping system will be time-critical due to the late start (cabling works in the zone) and the quantity of work on the systems. The interface to many systems, know to be important and time consuming, will need to be tested. At least 8 calendar weeks are required for testing the beam dumping system from the control room, assuming 50 % availability.

Dry runs are required for all systems and will be crucial for a smooth start with beam. No staged commissioning without beam will be possible. Thorough commissioning of the fully connected systems is mandatory for a reliable machine protection system, in particular the testing of the energy tracking and the triggering systems.

ACKNOWLEDGEMENTS

The work described in this paper would not have been possible without the contributions from many people, especially M. Barnes, E. Carlier, L. Ducimetière, B. Goddard, R. Jones, Y. Kadi, V. Kain, M. Meddahi and V. Mertens.

REFERENCES

[1] B. Goddard, "What did we learn with beam in 2008, Injection and Beam Dump", March 2009, these proceedings.

[2] M. Meddahi, "Transfer lines and Injection: results from machine studies during beam commissioning", March 2009, these proceedings.

[3] J. Uythoven, A. Antoine, E. Carlier, F. Castronuovo, L. Ducimetière, E. Gallet, B. Goddard,N. Magnin, H. Verhagen, "Results from the LHC beam dump reliability run', EPAC'08, 11th European Particle Accelerator Conference, Genoa, Italy - June 23-27, 2008.

[4] E. Gallet, J. Axensalva, V. Baggiolini, E. Carlier, B. Goddard, V. Kain, M. Lamont, N. Magnin, H. Verhagen, J. Uythoven, "Automatic post operational checks of the LHC beam dump system, EPAC'08, 11th European Particle Accelerator Conference, Genoa, Italy - June 23-27, 2008.