SECTOR TEST – PREPARATION HARDWARE COMMISSIONING

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Abstract

The preparation for the injection tests of the equipment described in the two previous presentations will be given in detail. The level of the commissioning of the equipment will depend on the time available between the cool down and the end of the injection test: this level can vary from the complete commissioning up to nominal current of all the circuits to the minimum current required for the injection test only for a limited number of circuits. The implications (organization of the work, coactivities with other sectors, etc.) of these scenarios will be described.

THE BASELINE

The baseline for the commissioning of the two sectors concerned by the sector test was already given in the Chamonix Workshop in 2004. Namely,

- Sectors 78 and 81 are completely installed before the injection test
- All the cryogenic subsectors of sectors 78 and 81 are at nominal temperature for the injection test
- All the circuits of sector 78 are commissioned for the injection test.
- All the circuits of sector 81 are not commissioned but only those required for the injection test.

It is worthwhile mentioning that the commissioning activity was intended as defined in the mandate of the Coordination for the Hardware Commissioning: all the equipment commissioned to nominal operating conditions of LHC.

The beam is threaded through the complete sector 78 up to and including Q6. Although, for sector 81 the beam is threaded only through the septa, Q5 until Q1, also the rest of the cold elements are required. In fact, in order to cool down even only one cryogenic sub sector of sector 81, all the connections to the QRL must either be made (SSSs or DFBs) or a temporary solution must be put in place in order to ensure the closure of the QRL and of the helium vessel (QRL and machine) as well as of the machine cryostat.

The conditions required for the sector test, as given in the web pages of the Sector Test with Beam Project[1], are listed below:

- TI8 operational
- Injection region fully commissioned
- Inner triplet, D1, D2, Q4, Q5 right of IP8 commissioned and cold
- Inner triplet, D1, D2, Q4, Q5, Q6, Q7, dispersion suppressor left of IP8 commissioned and cold
- Arc 78 commissioned and cold (not all the arc circuits are needed)
- Dispersion suppressor plus Q7 and Q6 right of IP7 cold
- Temporary dump region right of IP7

THE COMMISSIONING PROCEDURES

For all the equipment required for the sector test, which are detailed in the web pages of the Sector Test Project, the Hardware Commissioning Working Group had already prepared a set of standard commissioning procedures. These are described in documents [2,3,4,5,6] most of which were released after circulation for approval to the persons involved, departmental and project management; a few are in the last preparation phase.

For the superconducting electrical circuits, after the validation of the protection systems (see next section), the magnets are taken to different current levels.

At the *minimum stand-by current* of the power converter for each circuit, the protection functionalities of the powering interlock controllers and all its connected systems with current through the circuits is verified and the compatibility of the switch-on and switch-off processes of the converters with the sensitivity of the protection systems (namely QPS) are tested.

At *each subsequent current level*, (Injection level, 20%, 50%, 80% of $I_{nominal}$ and $I_{nominal}$) the following points are checked/validated:

- the power converter current control loops
- the protection mechanisms under real powering conditions and with limited amount of energy in the circuits
- to quench-related procedures, e.g. cryogenic recovery procedures
- the sensitivity and compatibility during ramps of the systems susceptible to noise pick-up, couplings, etc
- a last check on the polarities of the circuits by verifying voltages across current leads (at low current using QPS signals)

After the tests listed above, at each current level, the circuit is commissioned to operate at that current level with compromising its integrity. Therefore the partial commissioning program described below was adopted.

THE NEW SCENARIO AND ITS IMPACT

The conditions required for the test are slightly relaxed with respect to the baseline conditions which were stated in the Chamonix Workshop in 2004. In fact, only 118 out of 210 are required for the Sector Test in sector 78 and 18 in sector 81. Furthermore, for some of the circuits the level at which these are powered is also relaxed.

It was argued that for all the equipment other than the one used for injection, since the injected beam will not be accelerated, it is not really necessary to power the circuits

to nominal current. It was however requested to power the magnets up to 20% of nominal current in order to cycle the magnets and obtain similar conditions for every beam transfer.

This new scenario has a very big impact on the commissioning program. In fact, the standard procedures foresee a gradual powering of each circuit up to nominal current (even 12 kA for the main circuits) before the next circuit is taken for commissioning. Obviously, in the scenario proposed for the sector test the partial commissioning of the circuit interrupts this sequence and imposes a new overhead on the commissioning activity when it is restarted to complete the program for each circuit.

Nevertheless all the steps required to validate the protections systems, ensure electrical quality of the circuits and the associated equipment will not be impacted by the partial commissioning program: they will be carried-out completely. These tests are:

- The test of the power converters connected to the DC cables in short circuit, including controls for powering, ramp, monitoring
- The individual system tests of the Powering Interlock Control
- The individual system tests of the Quench Protection and Energy Extraction Systems
- Electrical Quality Assurance
- Post-Mortem System tests
- The interlock tests of each powering sub sector prior and after connection of the power cables to the DFB leads

The powering of those circuits which are not needed at nominal current will only be carried out up to 20% of $I_{nominal}$. This includes the main circuits which are the longest (10 days each) to commission.

The time required for the commissioning of the warm systems

The documentation describing the commissioning of this equipment (collimators, beam instrumentation, injection systems and the warm magnets), the numbers stated during the meetings of the Hardware Commissioning Working Group and in private discussions, indicate that the time required is 13 weeks after the installation of the equipment: this is independent of the cool down of the main cryostat. The last part (4-5 weeks) requires access restrictions to UA87 and RA87 before the high voltage tests of the kickers.

The time required for the partial commissioning of the superconducting electrical circuits

At the time of the commissioning of sectors 78 and 81, the teams foreseen for the commissioning of the LHC hardware across groups and departments will be available albeit not experienced. It is therefore foreseen to carry out this activity with four teams.

The first team would test the main circuits, a second team will be in charge of the separately powered quadrupoles, and the 60-120 A circuits, while the third team will commission all the 600 A circuits and the separation dipoles; the fourth team will be dedicated to the two inner triplet assemblies on each side of Point 8.

The commissioning of these circuits requires the magnets to be cold and will therefore be carried-out after the electrical quality assurance of the circuits and the cool down of the sectors. *The time required for these test cannot be reduced below five weeks.* It is worthwhile mentioning that the DFBs (A,M and Xs) will be cooled down and powered for the first time during the commissioning of sectors 78 and 81. Previous experience at String 2, where two weeks were needed to tune the cool down of the DFBS, suggests that their commissioning will not go smoothly.

While this can be achieved for sector 78 in the schedule presented by E.Barbero-Soto, it is not clear how the electrical quality assurance, cool down and the commissioning of those circuits required for the injection test can be achieved in the time given (4 weeks). It was argued that speeding up the production of the DFBAs could liberate 4 weeks which could make the test feasible.

CONCLUSION

It is clear that it takes substantially less time to partially commission sectors 78 and 81 for the sector test alone. More detailed and ambitious studies could show that even more time can be saved. However equipment safety must not be jeopardized: the decision to take shortcuts is in the equipment groups who, alone, have the prerogative of equipment safety.

Partial commissioning causes a major disruption of the commissioning program since the sequence of the operations within the test of each sector is modified and some time will be required to restart the commissioning of each sector that was interrupted.

It must be noted that, if this scenario is adopted, at the end of this year it seems unlikely that even one sector will have been completely commissioned.

REFERENCES

[1] http://lhc-injection-test.web.cern.ch/lhc-injection-test/

[2] LHC-D-HCP-0001 v.1.**0** General Procedure for the Commissioning of the Electrical Circuits of a Sector.

[3] LHC-MW-HCP-0002 v.1.0 General Procedure for the Commissioning of the Warm Electrical Circuits.

[4] LHC-D-HCP-0004 v.0.1 The Commissioning of the Hardware in the LHC Sectors : The Commissioning of the Inner Triplet Region.

[5] LHC-I-HCP-0001 v.1.0 The Commissioning of the Hardware in the LHC Sectors: the Injection Systems in Points 2 and 8 with their Associated Instrumentation.

[6] LHC-D-HCP-0003 v.0.5 The Commissioning of the Hardware in the LHC Sectors : Powering of the Superconducting Circuits of a Powering Sub-Sector up to Nominal Current