

MAGNET CIRCUITS

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Abstract

The LHC has 1572 superconducting circuits. Most of the time and resources during the Hardware Commissioning were consumed by tests of each circuit of the collider, the so-called powering tests. The tests consisted in carrying out several powering cycles at different current levels for each superconducting circuit. The number of tests needed for each sector was around 1500, thus more than 12000 for the whole machine. The aim for the 2009 campaign is to minimise the total time needed for re-commissioning these circuits before beam operation at 5 TeV. This will be done by reducing the number of steps needed for those circuits which have been already commissioned in a similar way as it was done for the second commissioning campaign in sector 4-5 and by optimising the test planning and execution applying the huge experience gathered in the last two years of powering tests.

THE LHC POWERING TESTS

The core of the LHC Hardware Commissioning was formed by the powering tests of the 1572 superconducting circuits. The activities carried out for each sector could be divided in two main parts: the preparation of the powering tests and the powering tests themselves.

Preparation of the Powering Tests

Some activities are needed to prepare the powering of the superconducting circuits before, during and after the cool-down of the sector. The most important ones are:

- Short-circuit tests of the power converters
- Electrical quality assurance (EIQA) at room temperature
- On-line EIQA monitoring during cool-down
- Commissioning of the DFBs at cold
- EIQA at cold (4.5 or 1.9 K)
- Connection of the DC cables to the current leads
- Individual system tests at cold of the quench protection system (QPS)

Powering Tests

Each superconducting circuit goes through different tests steps at different currents (from zero to nominal) before being released for beam operation. All the steps at a certain current level must be completed successfully in order to bring the circuit to higher current. The tests can be divided in four different groups (from lower to higher current):

- Interlock tests without current (PIC1)
- Configuration of the power converter (PCC)
- Interlock tests with current (PIC2)
- Tests at different current levels from minimum stable current till nominal (P2N)

- Powering groups of circuits (PGC)

2008 POWERING TEST CAMPAIGN

During the powering test campaign carried out from March till September 2008, 11122 tests were successfully carried out in the superconducting circuits of the eight LHC sectors. This represents more than 98% of the total tests planned and was essential for the successful injection tests done in August and the first circulating beams on September 10.

Lessons Learnt: Strategy

We extracted many lessons from the intense months of hardware commissioning last year. The most interesting ones in view of the future powering tests are the following:

- There is not an important difference between the time needed for commissioning the machine at 7, 5.5 or 4 TeV, except for the training quenches
- Commissioning up to a more conservative energy (3 or 4 TeV) will not make us save powering time, however, we have large experience in all the sectors below 5 TeV. This may reduce the risks and relax the planning and consolidations needs
- It is very important to know the parameters required for beam optics, such as the current ramp rate and acceleration, before starting the tests in order to ease the handing over of the circuits to the machine check-out team
- Commissioning of the matching sections and the inner triplets can be done in the shadow of the circuits in the arcs. Hence, full priority during the powering tests preparations must be given to the arcs.

Lessons Learnt: Efficiency

In average, when several sectors are in powering test mode we are able to use around 60% of the total time with operational cryogenic conditions. The rest 40% (time without tests going on) is mainly due to interventions needed in the tunnel and patrols. These figures can be improved if some measures are taken into account:

- When many interventions are required in the tunnel, these could be concentrated in normal working hours and use night/weekend shifts when necessary. This will reduce the number of patrols required and optimise the number of hours spent by experts in the control room.
- Automation of tests and analysis has been essential for reaching the target test rate. This has to be kept and improved wherever possible.
- Parallelism constraints and feasibility are now very well understood. As many fronts as possible should

be active during normal shift operation as long as safety (i.e. access control) is not compromised

- The Avis d'Intervention document (ADI) signed by the point owner is a very powerful tool for managing the intervention and tests going on in the tunnel.

Commissioning Status of the S.C. Circuits

The commissioning status of all the LHC circuits has been detailed in the eight EDMS documents released by the HCC team (one per sector) [1 to 8]. In parallel all the test data is stored in MTF and the different hardware commissioning web tools [9].

2009 POWERING TEST CAMPAIGN

Status of the Sectors before Powering

One of the main differences between last year powering test campaign and the one in 2009 will be that while in 2007 all the sectors were warm and no circuit had been powered, in 2009 we find the eight sectors in different cryogenic conditions, hence, the circuits have to be treated differently depending on the works carried out during the 2008-2009 shutdown:

- 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 during the shutdown (e.g. circuits in sectors 7-8 and 8-1)

According to this classification of initial conditions, different EIQA, PIC and P2N steps will be applied.

Access Conditions during Powering Tests

Before the incident in sector 3-4 on September 19, access was closed to the tunnel only when circuits were powered above 1kA. Access to the service areas and experimental caverns was always possible. After the incident, it was decided to close all the underground areas for the sector being powered and its adjacent ones (including experimental caverns).

This policy is currently being re-considered and in the coming weeks new access rules will be defined. This will have a major impact on the powering tests efficiency and scheduling (e.g. total time, manpower, number of patrols, parallelisms, etc.).

It is important to point out that most of the test steps (around 80%) are done at currents below 300A (see Figure 1). The decision on the maximum current value at which access to the tunnel will be permitted will therefore have a major impact on the development of the powering tests.

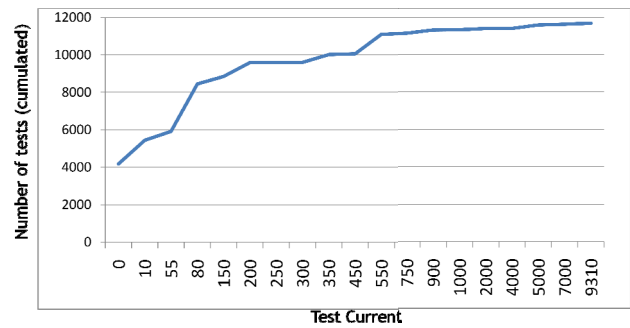


Figure 1: Number of tests done below a certain current.

Organisation of the Hardware Commissioning

The Hardware Commissioning Coordination unit (HCC) does not exist anymore and the team has been integrated into the Operations Group. This will preserve the know-how acquired during the last three years and at the same time help on a better integration of the powering tests activities with the machine check-out and beam commissioning.

The figure of the point owners will be kept and these will act as the link between the CCC crew and the different experts acting in the field. They will be also the responsible of tracking the commissioning status of the systems in the different sectors, define the commissioning priorities, define the short-term powering test planning and keeping the knowledge of the different system history through the different phases from the shutdown to the operation with beam.

Powering Test Procedures

The documents describing the powering tests procedures were prepared by the Magnet Performance Panel (MPP) together with the different system experts and the supervision of HCC. One document is released per circuit type and it is the main reference for the developing the different automation tools, databases, tracking tools, MTF, etc. It is very important that the documents are finished as soon as possible such that the powering test campaigns can be properly prepared.

For the 2009 campaign, in order to keep the good performance, reliability and quality reached during the last year tests, the powering procedures must be modified only if strictly necessary, however, some changes will be needed due to:

- New tests are required to commission the new hardware (e.g. QPS upgrade)
- Additional tests to avoid incidences (e.g. splice mapping, calorimetry)
- Some tests might be simplified in order to reduce the number of interventions in the field (e.g. energy extraction switches, power converters)
- Higher automation of the tests (e.g. QPS, converters)

Two kinds of documents will be released:

- Existing (updated) powering procedure: one document per circuit type, and
- For each sector: a document listing the steps to be applied or skipped for each circuit and a document with the sector specificities (special circuits)

sectors commissioned and ready for beam injection by September 2009 as planned.

CONCLUSIONS

The Hardware Commissioning team has already a large experience on preparing and executing the powering tests of the LHC superconducting circuits. The main goal for the 2009 campaign is to recover as soon as possible the performance level reached during summer 2008 while the last sectors were being prepared for the beam commissioning.

There are some open questions that need to be solved as soon as possible such as the new access conditions during the powering tests, the target energy at which the machine has to be commissioned this year, the new powering procedures to be applied, the available manpower for the commissioning shifts, etc. If no major unexpected issues are encountered we are confident on having the eight

REFERENCES

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- [8] LHC-MPP-HCP-xxxx (to be released)
- [9] <http://p2n.web.cern.ch/p2n/>