WHAT ELSE DID WE LEARN?

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Abstract

The tools developed to assist the Hardware Commissioning are presented. Differently from its definition, in fact, HC has required a massive support of Software applications, which had in turn to be commissioned. Apart the control applications, special software tools had to be developed to rapidly and smoothly allow a safe circuit commissioning.

The second part is devoted to the analysis of some "puzzlying and annoying" hardware problems that slowed down the commissioning and will possibly limit our test rate in 2009.

THE TOOLS

The commissioning of the LHC superconducting circuits was almost entirely completed in five months, last year. To obtain such a result, efficiency and automation have always been the key-drivers for the HC activity, above all in the development of the powering procedures and the related tools. We have been developing detailed procedure for the test of the superconducting circuits and we have as well learnt how to shorten these procedures to deal with a tight calendar, without any compromise with personnel and equipment safety.

For the re-commissioning, we will have to go a step back, since the procedures will have to be extended to cope with new verifications and new systems validation (high current circuits mainly):

- calorimetric measurements (they are needed for sectors not yet checked and we will possibly need to repeat measurements on the others)
- QPS snapshot for splice investigation
- validation of the n-QPS and QDS systems
- change of current levels for commissioning (according to the outcome on commissioning energy for this year, but also to the conclusions of the Safety Task-force on access with current)
- according to a sector history
- in agreement with change in commissioning parameters through ECRs.

The tools that were developed for years and assisted in speeding up the commissioning activity are mainly the Sequencer, the Post-Mortem browser, the PIC supervision, the QPS supervision and the web-based instruments.

The Sequencer

It has been the object of continuous improvements, becoming a powerful instrument, with very well defined and tested sequences and automatic entries. It is one of the keys for the speed-up of powering tests, witnessed by the fact that a tool to edit special cycles was developed, but never used: this is certainly because we went progressively towards the uniformity and automation of powering procedures.

Nevertheless it requires a lot of effort and man-power, to implement the sequences of test steps and to validate and debug those sequences. We will need to update the sequences according to the new powering procedures and this means that the new procedures must be ready much more in advance with respect to the beginning of the re-commissioning campaign.

Post-Mortem Browser

The PM tools have enormously increased test efficiency, with the PM_Event_Analyser interface which helps the experts to better follow test execution, to retrieve data for analysis and to stop continuation of tests in case of non-conformities; the EIC can better interact with experts, prioritizing request of signature.

As a further improvement this year, PIC test analysis and approval will be fully automated for the re-commissioning, apart for the 13-kA circuits.

What could be additionally improved is an automatic reporting/notification to system engineer to follow up non-conformities.

PIC Supervision

PIC [1] is the unique reference for event time stamp. It provides a practical way of locking circuits; very useful to:

- avoid powering of circuits with known electrical non-conformities
- temporarily block circuits with suspected issues
- avoid powering of leads with cooling problems
- redundant “condemnation” of a circuit prior to intervention
- preventively block all circuits after September 19 event.

Circuit locking was finally used in a wider way than foreseen, that’s why a second level locking (“super-lock”), on top of the existing one, has been recently created: the first-level lock will be used for temporary solutions, while the second one will be reserved to serious matter (i.e., a redundant “condemnation” of a circuit or a DFB or a powering sub-sector), with a dialog box for problem recording and a password protection.

The possibility of masking the Cryo-Start/Maintain interlock signal (sometimes used during the commissioning campaign) will be possibly still used, but remains a priority of PIC expert, always and only in

special cases and according to a well defined procedure of authorization/notification.

Recently, discussions have also been initiated on the possibility of a link between access and PIC: for details refer to [2].

QPS Supervision

A lot has to be done on the quench protection before re-commissioning [3]. Concerning the tools modifications, new control software will have to be developed for the n-QPS and QDS and for the QPS snapshots. The QPS team will have as well to replace all manual resets of QPS controllers with remote power-cycles (new units to be installed), to reduce at a minimum interventions in the tunnel.

An automatic script to close switches was already used during the 2008 Machine Check-out and will be extensively used this year, but not before circuit commissioning.

RBAC will be implemented in the supervision layer and the timing synchronization will be better improved; the communication problems, that were sometimes 'annoying' us, have been apparently sorted out [4].

Powering to Nominal Web Page (http://p2n.web.cern.ch/p2n/)

This was developed to assist and follow all aspects of the commissioning of the superconducting circuits, as the status of test execution for each sector, the date and other relevant test information (reason for test failure, circuit parameters, etc.); it was also used to track circuit non-conformities and to define the mission of the day.

Recently another web tool was developed to browse through all major commissioning events (quenches, failures, etc.), accessible from the following link: http://p2n.web.cern.ch/p2n/evdb/.

Other needs for the re-commissioning campaign are: a database mechanism to track parameters change (di/dt, acceleration, etc.), possibly in the form of a 'history' of LSA values, and an automatic tool to perform the calorimetric measurements. Furthermore, a confirmation of the capability of MTF to efficiently store more test campaigns is required.

The Databases

A particular attention has to be put on the two databases which are used as a reference for the commissioning activity: the LHC layout database and the LSA database. The first one is the DB holding the design values of the machine, including layouts, electrical circuits, LHC Equipment Catalogue (e.g. parameters for power converter and magnet types). It contains rather static data with strict version management (releases + release notes, changes to be documented in an ECR). This is why the second one is used as the operation database, for equipment control and setting, both during Hardware Commissioning and machine operation. The LSA DB offers, in fact, the required flexibility to adapt to changes of parameters, when needed.

The problem in using such a dynamic DB is that, to consistently distribute LSA changes, after every change a power converter expert must be consulted to synchronise the controller of the power converter. This means that frequent changes could result in temporary inconsistencies. One solution would be to ask the sequencer to do the synchronization automatically at the beginning of each test or to take LSA values as the reference for the controller, at least for some circuit categories.

HARDWARE PROBLEMS

Most of the problems that were "annoying" the commissioning activity have already been described in [5]. Some others are worth to be re-called, which could slow down the continuation of the commissioning for this year.

600A-10V LHC type power converters

The quench protection system for these circuits requires a smooth change in current, since the resistive component of the magnet load is calculated on the di/dt. The use of a derivative in the calculation requires for a long integration time, which is incompatible with reference jumps. Thus the calculation is only accurate for low di/dt and d^2i/dt^2.

Another problem [6] for this type of circuits is the fact that the power converters generate some distortion when crossing through zero voltage with current in the load (0V-crossing distortion). This is very specific from the 4-quadrant power converter, with the result of a voltage spike (not filterable at the converter level). PO made several measurements to characterize the zero-voltage-crossing distortion and the QPS team worked with PO to develop a filter to reduce the effect of the distortion on the voltage measurement (based on image processing techniques); the solution also improved QPS robustness to di/dt and d^2i/dt^2 parameters. Nevertheless, for a smooth commissioning and operation we need a trade-off between 'required' and 'allowable' parameters value (that is between the requirements of Physics for an infinite acceleration and those of QPS for a very limited acceleration), which may go to the detriment of operation and physics.

Another relevant point [7] for the 600 A power converters is the crowbar issue, mainly for the so-called type-B: for the circuits without energy extraction, when switching them off and due to the current still developed by the power stage, the activation of the crowbar could be dangerously delayed. To avoid such a problem a modification of the hardware for some RQS circuits and some correctors of the triplets (16 power converters in

total) has been asked, to install an early triggering of the crowbar (EDMS no. 977059).

Water Filters and Elettas

The water circuits in the machine feed, from the even point installations, all power converters and water-cooled cables of the superconducting circuits. 50 μm filters are installed on each power converter and water-cooled cable feeding and flow-meters ("Elettas") are put at the output of the water-cooled cable feeding-line as well as inside each converter. What was frequently observed during the commissioning campaign is the clogging of the filters with flow reduction, consequent triggering of the Eletta and power off of the circuit.

Filters were preventively and systematically cleaned before any long powering period, but HC and Machine Check-out were several times stopped because of this problem (several areas were treated 3-4 times).

It is important to observe that the filters are doing their job, blocking impurities that would possibly deposit inside the electronic equipment. A spectrometric analysis was performed on the samples and showed high content of Fe, Cr, Ni, Cu and their oxides (opening of the circuit for cleaning could contribute to oxidation and impurities accumulation).

Finally, at the end of last year, a decision was taken to change all filters around the machine from the present 50 μm to 100 μm mesh (already successfully tested in UA87); a total of around 1600 filters, with a complete cost of nearly 30 kCHF to be shared by CV, PO, EL.

Cable connections

During the short-circuit test campaigns, thermal imaging was many times used to look for hot spots on DC cable connections. In the future, cables will be sometimes disconnected, to perform ElQA tests on the DFB side or power converter check, and a re-qualification is needed.

On August 15, a 6-kA circuit was powered with a loosen cable connection on the DFB side, with the result of a high temperature increase of the connection. How to avoid current lead over-heating in the future? An alarm, based on temperature reading on current leads, is already available and a software interlock is being developed. Furthermore, the installation of thermo-switches has just been discussed, but the interlocking solution (link either to QPS, PIC or PC) is not yet defined. In the meanwhile, a temporary solution to detect bad connections has to be found. In fact, thermography will no more be possible in the underground areas, since safety issues raised after S34 incident will be making access conditions more severe, possibly preventing people in the underground areas when powering at high current. And the phenomenon is, of course, more relevant at high current. One solution could be the installation of "thermo-strips", to be used for visual spot checks after short high-current runs.

CONCLUDING REMARKS

The software tools that helped the commissioning of the superconducting circuits in 2008 will be the basis for an efficient re-commissioning this year. Many modifications/improvements are, nevertheless, going to be carried out, which will ease some tasks, on one side, but also add complementary verifications.

The hardware problems that were slowing down the commissioning activity are on the way for a solution, but a compromise has to be sometimes looked for.

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