INFORMATION MANAGEMENT WITHIN THE LHC HARDWARE COMMISSIONING PROJECT

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Abstract

The core task of the commissioning of the LHC technical systems was the individual test of the 1572 superconducting circuits of the collider, the powering tests. The two objectives of these tests were the validation of the different sub-systems making each superconducting circuit as well as the validation of the superconducting elements of the circuits in their final configuration in the tunnel. A wide set of software applications were developed by the team in charge of coordinating the powering activities (Hardware Commissioning Coordination) in order to manage the amount of information required for the preparation, execution and traceability of the tests. In all the cases special care was taken in order to keep the tools consistent with the LHC quality assurance policy, avoid redundancies between applications, ensure integrity and coherence of the test results and optimise their usability within an accelerator operation environment. This paper describes the main characteristics of these tools; it details their positive impact on the completion on time of the LHC Hardware Commissioning Project and presents usage being envisaged during the coming years of operation of the LHC.

THE COMMISSIONING OF THE LHC SUPERCONDUCTING CIRCUITS

Each one of the 1572 superconducting circuits forming the LHC collider has to be carefully commissioned before injecting beam into the accelerator.

The circuits have been classified into nine groups (circuit types) depending on their maximum current and the associated protection system. Detailed commissioning procedures have been prepared by the system experts and the Hardware Commissioning Coordination (HCC) team for each circuit type. Each procedure consists on a sequence of tests to be carried out at different current levels. A circuit is never powered to a higher current unless all the tests at the previous current are successfully completed. These tests are usually called *steps* and the sequence of steps that a circuit has to complete during its commissioning are the *profiles*. A step consists on the following actions, which have to be performed in the indicated order:

- Verify that the previous step is properly completed
- Get the information related to the step and the circuit being tested from the commissioning databases
- Launch the execution of the tests, normally consisting on the restart of the power converter, ramp up of the circuit to the test current and performance of an action at the current plateau (simulated failure, quench, electrical measurements, energy extraction, etc.)
- Collection and analysis of the test result data. This is done during or after the tests (online/offline) depending on the test type
- Approval or rejection of the test results by the system experts involved on the tests, helped by software tools
- Store the test result in the MTF database (see below)

The operator does some of these actions manually, however, special effort has been put on automating as much as possible the whole sequence so most of the actions do not require human intervention.

A set of software tools have been developed in order to assist the hardware commissioning team and the control room crew when performing these tests, and to prevent them from doing mistakes like powering circuits to a current level for which the circuit has not been validated, or powering circuits that should not be powered due to non-conformities.

Special care has been taken on keeping the tools consistent with the LHC quality assurance policy, avoid redundancies between expert work and applications, ensure the integrity and coherence of the tests results and optimise their usage during the very intense days of the LHC commissioning.

The developed tools can be divided in two types:

- The Sequencer: operation tool used by the operator for performing automatically the test sequences
- The information management tools

This paper describes the information management tools.

INFORMATION MANAGEMENT TOOLS

The different applications and databases used during the hardware commissioning to manage the large amount of information are presented below.

LSA Database

LSA (LHC Software Architecture) is the software infrastructure for LHC operation including a database with the information related to the powering tests: test plans foreseen for each circuit types (steps), executed tests, specific information for each circuit, etc.

The online-data used by the sequencer and other applications are stored in this database.

It should be stressed that this database is not limited to hardware commissioning, but is the central database used during the collider operation with beams.

LHC Layout Database

The LHC layout database [1] has been the working reference during the design, integration, installation and commissioning of the collider. It regroups the three points of views of the collider design: mechanical, optical and electrical in a single database.

While the LSA database is a flexible operational information source whose data is constantly modified, for instance when a new test result is uploaded or a circuit status modified, the layout database is a rigid reference that is only used during the commissioning for getting information about the tested systems and can only be modified following very strict versioning protocols which are out of the scope of the hardware commissioning.

MTF Database

If the layout database gives the input to the hardware commissioning, the MTF [2] is a quality assurance tool used for storing its outputs.

This database contains the test profile (i.e. sequence of steps) linked to each superconducting circuit. When a test is completed (successfully or not) and all the system experts have signed the test result, the information is uploaded in MTF. This includes:

- Test execution information: date, operator, electrical parameters used, etc.
- Test result: OK-not OK
- Analogue and digital measurements taken during or after the tests in order to evaluate the system performance (i.e. properties)

MTF is the database in which the results of the hardware commissioning project will be kept through the lifecycle of the LHC.

Powering to Nominal (P2N) Webtool

The P2N webtool was developed to assist and follow all the aspects of the commissioning of the LHC superconducting circuits. Originally it was a simple progress report in the form of a matrix where all the circuits and their associated test plans (i.e. test executed or planned for execution) where displayed. However, while the commissioning project was advancing, many other features were added as ideas coming from daily experience in the control room were taken into account.

- Detailed test plan: it is the main tool to follow the commissioning. As it can be seen in Figure 1, for each circuit it shows its technical information (e.g. circuit type, interlock type, powering subsector, etc.). It give an overview of its commissioning and information about the last test executed on the circuit. Finally the whole test plan (tests foreseen to be executed) is represented in different colours depending on the state (execution pending, execution in progress, test skipped, executed successfully or executed unsuccessfully).
- Mission of the day: list of tests scheduled for the current day. The tool provides to the commissioning coordinators with a way to easily define for the operators and engineers in charge the list of steps planned for the day together with its preferences. The webtool uses a simple colour code to assist the operation crew on choosing the proper test to be done each time in order to cope with the daily powering agenda.
- Circuits needing attention: when a non-conformity or a non-expected behaviour is noticed for a circuit, the commissioning responsible will take the appropriate measures to keep the circuit safe. The P2N webtool will indicate which circuits can be powered and which ones not (due to a non-conformity). It also allows the responsible to release the circuit for powering once the non-conformity is solved.
- Documentation: the P2N webtool also acts as interface between the different information associated to the commissioning of each circuit. By choosing a single circuit, the user can easily access the relevant circuit data stored in the LSA and the layout databass, the technical specification describing the powering procedure for that circuit type and the data linked to that circuit in MTF.

The P2N webtool has been the central tool used for the daily operation in the control room during the 2008 commissioning and is currently being adapted to play the same role during 2009 and future campaigns.

The Commissioning Dashboard

While the P2N webtool has an approach on a circuit basis, the dashboard was conceived to give a complete overview of the commissioning of a whole sector in a single screen. The circuits are grouped by cryostat and circuit type and the performed tests are reflected in evolution charts. Below each chart the total number of circuits and the percentage already commissioned is displayed.

This tool gives the global overview of the superconducting circuit commissioning status for the whole machine.

The Event Database

The event database project started as a way to classify and group all the post-mortem events logged in the post-mortem system using a more rational and human-oriented approach.

In this way, the single post-mortem dumps arriving to the system from the different systems (e.g. power converters, quench protection system, powering interlock, etc.) are processed using different criteria, grouped and classified into different categories (e.g. training quench, provoked magnet quench, power converter failure, etc.). This is done thanks to the so-called *event building* application, which collects the information about a specific event which would otherwise be available but scattered between systems.

A webtool acts as interface between the user and the database allowing an easy and fast access to the different events occurred during the hardware commissioning campaigns.

CONCLUSIONS

A powerful set of software tools has been developed during the years of the LHC hardware commissioning to cope with the large amount of information managed during the first powering of the LHC superconducting circuits.

These tools have been very useful for both keep the high quality standards required for the operation of such a complex machine and optimise the time needed for commissioning such that the ambitious schedule milestones of the LHC project could be respected.

REFERENCES

[1] S. Chemli et al. "LHC Reference Database: Towards a Mechanical, Optical and Electrical Layout Database", EPAC'04, Lucerne, July 2004, WEPLT025; http://www.JACoW.org.

[2] E. Barbero-Soto and F. Rodriguez-Mateos. "Hardware Commissioning of the LHC: Quality Assurance, Follow-up and Storing of the Tests Results", ICALEPS'05, Geneva, October 2005.

CIRCUIT NAME	LAST PASSED TEST	TESTS EXEC	LAST EXEC	SUC	UNDER EXEC	EXECUTION PLAN								
ROD.A34B1	PIC2 TEST HW LINKS	9 / 14 (64%)	PCS	N	_	PCL	PCC.5	PIC2	PCS	PLI3.b1	PNO.d3	PNO.b1	PNO.a3	PIC2 GPM
ROD.A34B2	PLI3.b1	11 / 14 (78%)	PNO.d3	N	_	PCL	PCC.5	PIC2	PCS	PLI3.b1	PNO.d3	PNO.b1	PNO.a3	PIC2 GPM
ROF.A34B1	PIC2 TEST HW LINKS	9 / 14 (64%)	PCS	N	_	PCL	PCC.5	PIC2	PCS	PLI3.b1	PNO.d3	PNO.b1	PNO.a3	PIC2 GPM
ROF.A34B2	PCS	10 / 14 (71%)	PCS	Y	_	PCL	PCC.5	PIC2	PCS	PLI3.b1	PNO.d3	PNO.b1	PNO.a3	PIC2 GPM
RQS.A34B2	PLI3.b1	11 / 14 (78%)	PLI3.b1	Y	_	PCL	PCC.5	PIC2	PCS	PLI3.b1	PNO.d3	PNO.b1	PNO.a3	PIC2 GPM
RQTL9.R3B1	PIC2 TEST HW LINKS	9 / 14 (64%)	PCS	N	_	PCL	PCC.5	PIC2	PCS	PLI3.b1	PNO.d3	PNO.b1	PNO.a3	PIC2 GPM
RQTL9.R3B2	PCS	10 / 14 (71%)	PCS	N	_	PCL	PCC.5	PIC2	PCS	PLI3.b1	PNO.d3	PNO.b1	PNO.a3	PIC2 GPM
RSS.A34B1	PIC2 TEST HW LINKS	9 / 14 (64%)	PCS	N	_	PCL	PCC.5	PIC2	PCS	PLI3.b1	PNO.d3	PNO.b1	PNO.a3	PIC2 GPM
RSS.A34B2	PLI3.b1	11 / 14 (78%)	PNO.d3	N	_	PCL	PCC.5	PIC2	PCS	PLI3.b1	PNO.d3	PNO.b1	PNO.a3	PIC2 GPM
RQS.R3B1	PIC2 TEST HW LINKS	9 / 12 (75%)	PCS	N	_	PCL	PCC.5	PIC2	PCS	PNO.d3	PNO.a3	PIC2 GPM		
RQT12.R3B1	PIC2 TEST HW LINKS	9 / 12 (75%)	PCS	N	_	PCL	PCC.5	PIC2	PCS	PNO.d3	PNO.a3	PIC2 GPM		
RQT12.R3B2	PCS	10 / 12 (83%)	PCS	N	_	PCL	PCC.5	PIC2	PCS	PNO.d3	PNO.a3	PIC2 GPM		
RQT13.R3B1	PNO.d3	11 / 12 (91%)	PNO.a3	N	_	PCL	PCC.5	PIC2	PCS	PNO.d3	PNO.a3	PIC2 GPM		
RQT13.R3B2	PNO.d3	11 / 12 (91%)	PNO.a3	N/WPM	_	PCL	PCC.5	PIC2	PCS	PNO.d3	PNO.a3	PIC2 GPM		
RQTL10.R3B1	PIC2 TEST HW LINKS	9 / 12 (75%)	PCS	N	_	PCL	PCC.5	PIC2	PCS	PNO.d3	PNO.a3	PIC2 GPM		
RQTL10.R3B2	PCS	10 / 12 (83%)	PCS	N	_	PCL	PCC.5	PIC2	PCS	PNO.d3	PNO.a3	PIC2 GPM		
RQTL11.R3B1	PIC2 TEST HW LINKS	9 / 12 (75%)	PCS	N	_	PCL	PCC.5	PIC2	PCS	PNO.d3	PNO.a3	PIC2 GPM		
RQTL11.R3B2	PCS	10 / 12 (83%)	PNO.d3	N	_	PCL	PCC.5	PIC2	PCS	PNO.d3	PNO.a3	PIC2 GPM		
RQTL7.R3B1	PIC2 TEST HW LINKS	9 / 12 (75%)	PCS	N	_	PCL	PCC.5	PIC2	PCS	PNO.d3	PNO.a3	PIC2 GPM		
RQTL7.R3B2	PIC2 TEST HW LINKS	9 / 12 (75%)	PCS	N	_	PCL	PCC.5	PIC2	PCS	PNO.d3	PNO.a3	PIC2 GPM		
RQTL8.R3B1	PIC2 TEST HW LINKS	9 / 12 (75%)	PCS	N	_	PCL	PCC.5	PIC2	PCS	PNO.d3	PNO.a3	PIC2 GPM		
RQTL8.R3B2	PCS	10 / 12 (83%)	PCS	N	_	PCL	PCC.5	PIC2	PCS	PNO.d3	PNO.a3	PIC2 GPM		

Figure 1: Example of the test sequences visualization for a group of circuits using the P2N webtool. Each row represents the status of a single circuit: tests completed OK (green), failed tests (red), tests being analised (orange) and tests to be done (grey).