SCHEDULING THE POWERING TESTS

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Abstract

The Large Hadron Collider is now entering in its final phase before receiving beam, and the activities at CERN between 2007 and 2008 have shifted from installation work to the commissioning of the technical systems ("hardware commissioning"). Due to the unprecedented complexity of this machine, all the systems are or will be tested as far as possible before the cool-down starts. Systems are firstly tested individually before being globally tested together. The architecture of LHC, which is partitioned into eight cryogenically and electrically independent sectors, allows the commissioning on a sector by sector basis. When a sector reaches nominal cryogenic conditions, commissioning of the magnet powering system to nominal current for all magnets can be performed.

This paper briefly describes the different activities to be performed during the powering tests of the superconducting magnet system and presents the scheduling issues raised by co-activities as well as the management of resources.

INTRODUCTION

The Large Hadron Collider (LHC) is installed in a circular tunnel 27km long, and is divided in eight sectors of equal length; one sector is composed by two half Long Straight section (2*0.25km housing superconducting magnets and room temperature components) and one arc (2.9km housing superconducting magnets composing the continuous cryostat). The utilities (electricity, cooling and ventilation, cryogenics...) are installed in the four even points and in point 1.8, and are distributed in the two adjacent sectors, which allow the commissioning on a sector by sector basis [1]. The hardware commissioning of the LHC consists of the Individual System Tests (IST), the Cool-Down of the machine, and the Powering Tests of each sector in order to ensure a safe and efficient machine start-up without being plagued by technical problems: In summary a thorough commissioning of technical systems without beam.

INDIVIDUAL SYSTEM AND SHORT CIRCUIT TESTS

More than fifteen systems (not including all beam systems nor the experiments) are involved in the commissioning phase. After delivery and installation at CERN, each system was individually tested to assess its performance: cryogenic line pressure and leak tests, collimator tests, Powering Interlock System tests, Energy Extraction tests, Beam Instrumentation tests, Injection and Beam Dump systems tests, Cryogenics Instrumentation tests, etc. These individual system tests were scheduled in parallel with the installation, within tight constraints [2]. The first step towards the powering tests is the Short Circuit Tests that represent the first phase of a global commissioning where the warm part of the superconducting circuits is validated. It is during this phase that the infrastructure systems are extensively tested and validated [3].

COOL-DOWN

All the refrigerators and ancillary cryogenic equipment are concentrated in five cryogenic "islands" which supply through the cryogenic line (QRL), the superconducting magnets (arcs, dispersion suppressors, inner triplets) and the RF superconducting cavities [4]. During the cool-down the objective is to get to the conditions needed for the powering of the magnets. Two signals are used to give the "green light": the Cryo_Start (start-up interlock) and Cryo_Maintain (stop interlock). There are three sub-phases during the cool-down:

- Cool-down from 300K to 4.5K
- Liquid helium filling at 4.5K
- Cool-down from 4.5K to 1.9K

Once 1.9K is attained, and the cryogenic instrumentation tested, the powering tests can start.

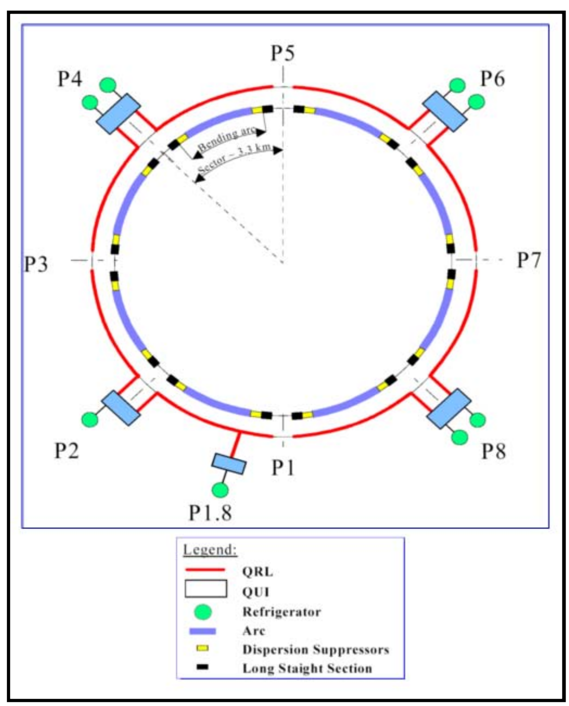

Figure 1: LHC cryogenic system

POWERING TESTS

The Powering Tests are divided in two phases, the preparation for the Powering Tests and the actual Powering tests.

Preparation for the powering tests

It includes:

- The electrical quality assurance “at cold” to qualify and measure electrical parameters of each superconducting electrical circuit, including the current leads of the Distribution feed Boxes
- The tests of the Quench Protection System “at cold” to verify the correct installation of the quench protection equipment with respect to the corresponding implementation plans
- The interlocks tests without current in the magnets to commission the protection functionalities of the power interlock controllers and all the connected systems,
- The commissioning of the electrical feed boxes (DFBs) and of the cryogenically stand alone magnets without current to check the lead-heat heaters, check the DFB liquid helium, measure the temperature of each cryostat chimney, establish the mass flow through the current leads and measure the boil-off rate of the DFB at zero current [5].

The actual Powering Tests

When the preparatory activities are finished, the power converters are connected to the current leads of the Distribution Feed boxes and the powering tests follow:

- Interlock tests at minimal operational current to commission the protection functionalities of the powering interlock controllers and all their connected systems with current through the circuits.
- Power “to nominal” each circuit: Circuits with energy extraction system and quench heater will need to go through all the levels (20%-50%-70%-100% of nominal current) while those protected internally by the power converter will be tested directly at nominal current. At each current level the circuit will go through different steps (depending on its type, the circuit will go through more or less steps): current cycle to the test current, forced energy extraction, provoked quench, simulation of a forced power abort from the powering interlock, simulation of a powering failure of the converter, simulation of a slow power abort from the powering interlock verification of the current leads performance [6].

SCHEDULING ISSUES

The powering tests program has been prepared during installation, together with the owners of the various systems and documented in detail for each phase. The Work Break Down structure was established at an early stage in order to define and organize the activities. The durations and dependencies between tasks were estimated by following the experience in String I, String II and Hera project.

Original program

The original program foresaw to power test each sector at a time within a period of around twelve weeks (depending on the characteristics of each sector). A wide study was done to evaluate the needs in term of resources (personnel and budget). To identify easily new requirements and react quickly in case of schedule changes, some actions have been undertaken:

- Resources
  - The resources have been grouped in teams
  - Each task has one or more teams
  - The human resources have been classified in different categories depending on the type of contract (e.g. CERN staff, collaborations with national institutes, etc.)
  - Personnel presence has been defined in two main categories : in the field and on call
- Classification: circuits types have been classified based on the type of global protection and power converter DCCT current;
  - 13kA main circuits: main dipoles and main quadrupoles circuits
  - IP circuits: Individually powered dipoles
  - IP Quad: Individually powered quadrupoles
  - 600EE: 600A correctors with external energy extraction
  - 600 EE crowbar: 600A correctors with energy in the converter
  - 80-120A: 80-120 A corrector circuits
  - 60A: 60A closed orbit corrector circuits

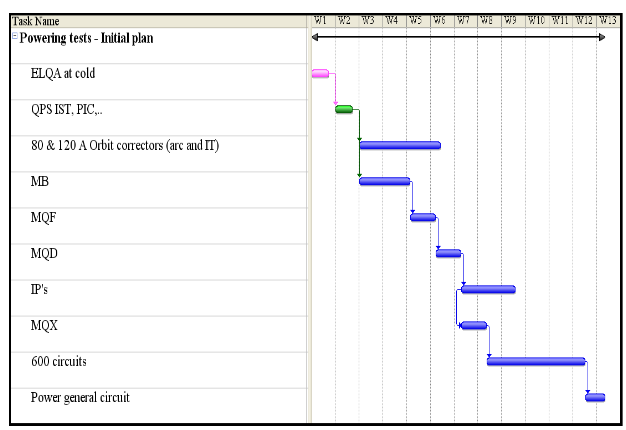

Figure 2: Initial commissioning plan per circuits

Evolution

In 2005, as a result of different delays encountered with the cryogenic line installation and the inner Triplets incidents, the allocated time for the powering tests was drastically reduced from an initial total period of 28 months to a period of 13 months [7]. As a consequence the resources allocated to each task had to be increased, and the powering tests were planned to be carried out in more than one sector at a time. The classification of circuits and the resource studies helped a lot in this difficult exercise. Additional resources were found through the different institutes collaborating with CERN.

In March 2007, the powering tests in the first sector started. Despite the very slow start-up due to a low Mean Time Before Failure and High Mean Time To Recovery of the cryogenic (weak points have been identified during the first cool-down and are being solved), these first tests allowed to optimize the sequence and durations of tasks, and thus refine the schedule.

In March 2008, Taking into account the latest delays, and in order to meet the target of a beam in LHC before the end of this summer, the decision was taken to qualify circuits at least for 5TeV, allowing time dedicated to powering tests in each sector to be reduced by limiting the number of quenches, and allowing the power tests of the 600-120-80-60A circuits in parallel with the main circuits (i.e.: 13kA and IPs).

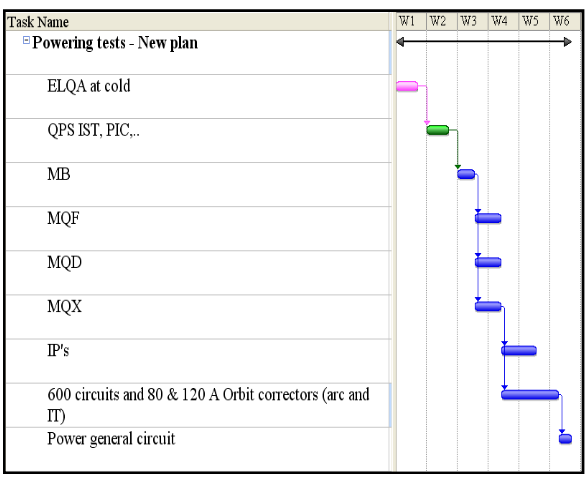

Figure 3: New commissioning plan per circuits

Schedule follow-up and tools

The limited resources and the aggressive strategy adopted for the schedule imply the need of a rigorous day by day scheduling and follow-up.

Moreover due to the large number of test sequences and procedures applied to the different systems and components, the information needs to be structured and managed following a strict quality assurance method. The Manufacture and Tests folders of the Hardware commissioning (HC MFT) are used to archive the results of the tests (i.e. status, parameters, etc.) which will be used later as a reference during the operation with beam, and to monitor the progress of the different tests and ensure a correct follow-up of the procedures described in the engineering specifications [8].

CONCLUSION

The hardware commissioning team has adopted a pragmatic approach: What needs to be done, how, and when were documented for all the parts of the machine and for all the phases. Moreover the team has implemented a computer quality assurance plan. The daily follow-up of the tests allowed us to promptly react when a problem was detected and to take the adequate compensatory measures (rescheduling, works re-organization).

With the dynamic teams involved in powering tests, and the global motivation for the start up of the machine, we are now confident to start the beam commissioning during this summer.

ACKNOWLEDGEMENTS

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