THE COMMISSIONING OF
THE LHC TECHNICAL
SYSTEMS

the commissioning unit is a sector

- there are 8 sectors
- the utilities and the machine systems are sectorised
- assembly and commissioning almost independent
a systematic approach

…..to unprecedented complexity

1. The systems to be commissioned in the cold sections of the machine
   - magnets, power converters, interlocks, quench detection and energy extraction system
   - the associated utility systems such as AC distribution, water cooling, ventilation, access control and safety systems

2. The systems in the long straight sections
   - injection, RF, beam dump, beam instrumentation, collimators, magnets, power converters, interlocks, etc.
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a methodology for the commissioning of the technical systems and their interactions, preparation started in 2003

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the mandate & the strategy

1. After the qualification for operation of the individual systems of a sector (vacuum, cryogenics, quench protection, interlocks, powering, etc.).

2. Each sector will be commissioned as a whole up to the powering to nominal current of all the circuits.

3. Validation and specific studies will be carried-out on the first commissioned sector.

- design the procedures
- evaluate the resources needed
- build the necessary environment (documentation, test folders, analysis tools, logbooks, collaborative tools, web pages, reporting structure, etc.)
procedures & documentation

GENERAL PROCEDURE FOR THE COMMISSIONING OF THE ELECTRICAL CIRCUITS OF A SECTOR

Abstract
This document describes the sequence of the steps which lead to the commissioning of the electrical circuits of each sector. It gives the backbone of the general procedures and refers to more detailed documents which in turn describe the individual system tests and hardware commissioning procedures.

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the test folder

## Individually Powered Dipole Circuit

<table>
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<tr>
<th>Slot Name</th>
<th>01-HCA PIC1.1 Tests Software Link (PIC-Cryo)</th>
<th>02-HCA PIC1.2 Tests Software Link (PIC-QPS)</th>
<th>03-HCA PIC1.3 PC Permit</th>
<th>04-HCA PIC1.4 Powering Failure</th>
<th>05-HCA PIC1.5 Circuit_Quench via QPS</th>
<th>06-HCA PIC1.6 Fast_Abort_Request via PIC</th>
<th>07-HCA PIC1.7 Discharge_Request via PIC</th>
<th>08-HCA PIC1.8 Discharge_Request via PIC</th>
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**Export data to an excel file.**

Created on Thursday, 2007-6-21 for SABAN HwC Slots Step Report

HwC Step report for slots

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The objective is to validate

1. the warm elements of the circuits
   - the power converters,
   - the energy extraction system,
   - the powering interlocks,
   - the normal conducting cables
2. the utilities
   - demineralised water for cooling,
   - ventilation,
   - AC current supply and cables
24 hour run of all the power converters at ultimate and then at nominal current.

The stability of
1. the current
2. the AC supply
3. the temperatures
   - of the demineralised water,
   - of the air,
   - of the electronics,
   - of the cables
are recorded in order to validate the correct functioning of the whole area.

Powering areas contain between 34 to 81 power converters
22 out of 29 powering areas now qualified

Not always successful, some need to be repeated (reasons EMC, ventilation, heating of powering cables)
During cool-down, all the circuits go through different electrical quality assurance tests at several temperature levels.
First results

Sector 78: Electrical Quality Assurance & Cool down

Simplified graph showing the evolution of magnet temperatures in Sector 78

Circuits go through different electrical quality assurance tests at several temperature levels.
First results

Sector 78: Electrical Quality Assurance & Cool down

Simplified graph showing the evolution of magnet temperatures in Sector 78

Quench of RQF

circuits go through different electrical quality assurance tests at several temperature levels.
First results

Sector 78: Electrical Quality Assurance & Cool down

Simplified graph showing the evolution of magnet temperatures in Sector 78

Quench of RQF

Magnet temperature profile along sector 78 at 19:35 Jun 23
the commissioning of the superconducting circuits
the commissioning of the superconducting circuits

Subsector Preparation for Powering Tests

- Interlock Tests Correctors w/o Current - PIC1
- Cryogenics OK for the Subsector
- Electrical Quality Assurance @ Cold
- Interlock Tests Main Circuits w/o Current - PIC1
- Connection DC Cables - Leads
- DFB Commissioning without Current

Subsector Powering Tests

- Interlock Tests with Current - PIC2
- Powering to Nominal

4.5K  1.9K  4.5K
the commissioning of the superconducting circuits

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Subsector Powering Tests

- Interlock Tests with Current - PIC2
  - Powering to Nominal

4.5K  MBB  MBA  MBB  MBA  MBB  QPS  QPS  QPS  QPS  QPS  1.9K  4.5K

DFBAN  MBA  MBA  MBA  MBA  DFBAN

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the commissioning of the superconducting circuits

Powering Tests

1. interlock tests at minimum operational current
2. validation at different current levels (injection, 20, 50 and 70%) followed by powering to nominal current
   - ramp up to the test current
   - verification of the current leads performance
   - forced energy extraction
   - provoked quench
   - simulation of a Fast Power Abort from the powering interlock
   - simulation of a failure of the converter
   - simulation of a Slow Power Abort by the powering interlock

The aim of these tests is the validation of the protection mechanisms under the different failure scenarios and the behaviour of the components of the circuit during a normal LHC ramp and steady state
First results
the commissioning of the superconducting circuits

51 magnets over 2.7 km
0.286 H total inductance
First results
the commissioning of the superconducting circuits

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First results
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A current cycle of the powering of two matching section quadrupoles Q4 and Q5 left of Point 8 and the recombination dipole D2 that is powered via the same DFB as Q4.

During first powering of this ensemble a coupling was observed: after D2 had been taken to its nominal current (6 kA), when the current in one of the two apertures of Q4 was increased, a quench in D2 was observed. The figure shows a later powering where this was not observed.
Current for two twin quadrupole magnets and one dipole magnet

Current versus time for 5 electrical circuits

- quench and current discharge
- current ramp
Current for two twin quadrupole magnets and one dipole magnet.
zoom – Q4 during ramp and discharge

Current increase, decrease and quench for both Q4 aperture (zoom)
This first experience with the commissioning of Sector 78 has validated preparation, environment, procedures and tools which had been carefully setup during the last two years.

Although only very limited time was available, valuable experience was gained during the first powering tests of superconducting magnets. For the first time, all systems involved in the powering performed successfully together: power converters, powering interlock system, magnet protection system and associated controls.

Cryogenic quench recovery can be very fast....
First powering of the main dipole magnets in sector 7-8, 154 dipoles with a total inductance of 15 Henry.

having been involved in the beam commissioning of several accelerators: LHC Hardware Commissioning is as exciting.