Cryogenic Electrical powering for the LHC

Conceptual Design of the Cryogenic Electrical Feedboxes and the Superconducting Links of LHC

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Outline

- Cryomagnet powering
- Cryogenic Electrical Feedboxes DFBs
- Superconducting links DSL
Aerial view of CERN
The Large Hadron collider

Superconducting magnets
Layouts of the LHC IR 1 - 4

DFB Project

DFBM

DFBA

Optics ver. 6.4

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Powering of the LHC cryomagnets

Supply of current to LHC superconducting magnets
- 1300 terminals
- 2900 kA total current
- several busbars types

Requirements
- Supply high current to 1.9K or 4.5K magnets
- reliable operation using existing cryogenics
- Tunnel integration & transport
- compatible with the power converters & cabling integration
- various types of magnets & busbars

Current supply
- Tunnel integration
  - Inner triplet
  - CC correctors
  - End of arc
  - Standalone magnets
  - Remote cryo supply
  - Inconvenient/impossible Tunnel integration

Electrical feedback
- DFBX
- DFBA
- DFBM
- Cryostat
- DSL + DFBL
DFBs: Functionalities & interfaces

- WRL
- QRL
- DFB
- Magnets
- Control & supervision
- DC powering & protection
- Supports
- Beam pipes
- Interfaces

DFBs:
- Functionalities & interfaces
- Cryogenics
- Helium
- Control & supervision
- DC powering & protection
- Alignment
- Cryogenics
- Current
- Forces
Functionalities of the DFBs

**Current supply to the LHC cryomagnets**

1300 current leads, 2900 kA total current, 44 boxes, incorporating from 2 to 71 current leads in 3 main types

- applies to: all DFBs
- subfunctionalities
  - electrical functions
  - cryogenics/current leads related functions
  - connection to DSL

**Arc termination**

- applies only for DFBAs
- subfunctionalities
  - end of arc forces recovery
  - precise alignment under vacuum & cold conditions
  - supply of cryogenics to arc magnets
  - beam pipes support & alignment
  - special thermal contraction compensation

**Cryogenic fluids for the superconducting links**

- applies to: only for DFBLs
## List of DFBs & circuits

### Totals

<table>
<thead>
<tr>
<th></th>
<th>13kA</th>
<th>6kA</th>
<th>600A</th>
<th>120 A</th>
<th>Chimneys</th>
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### 23 DFBM

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### TOTAL

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### 5 DFBL

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<td>44</td>
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<td>48</td>
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Tunnel integration

Ø4400 tunnel

Beam pipes

Reserved for transport

Ø3800 tunnel

Reserved for transport
Basic configurations

3 types of DFBs
- 16 DFBA
- 24 DFBM
- 5 DFBL

Driving factors
1. Functionality, availability, quality of beam
2. Optimization of design & validation time
3. Limited design and R&D resources
4. Standardization, simplification

DFBA
- IR 3DSL interface
- DSL feedbox
- IR3

DFBM
- current leads module
- Low current module

DFBL
- current leads modules
- Low current module

DFBA
- Magnet interface
- Shuffling module
- Low current module
- IR1,2,4,5,6,8
- High current module
- All IR

Driving factors
- One current lead integration type
- 2 current leads modules types
  - high current: 13kA + 6 kA (600A IR 3 & 7)
  - low current: 6kA + 600 A
- Interface variants

DFBM
- Magnet interface
- Low current module

DFBL
- DSL interface
- DSL feedbox
- Low current module
- Low current module
DFBAA configuration

- Low current module 6kA & 600A leads
- High current module 13kA & 6kA leads
- Current lead chimneys
- Vacuum equipment VAA
- Jumper cryo connection to QRL
- Supporting beam
- Removable door
- SHM/HCM interconnect
- HCM/LCM interconnect

Configuration of DFBAO IR8 left

DFB Project

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DFBA support system

DFBA shuffling module

Connection to magnets

Alignment targets

Thermal screen

Beam pipes

Beam screen system

Jack
DFB configurations

DFBLA

- 12x120A CLs
- 11x6kA CLs
- service chimney
- interface to DSL
- removable door
- interface to QRL

connection to magnet

DFBMA

- 5x6kA CLs
- service chimney
- removable door
- 12x120A CLs

DFB configurations

DFBLA

- 12x120A CLs
- 11x6kA CLs
- service chimney
- interface to DSL
- removable door
- interface to QRL

connection to magnet

DFBMA

- 5x6kA CLs
- service chimney
- removable door
- 12x120A CLs

DFB configurations

DFBLA

- 12x120A CLs
- 11x6kA CLs
- service chimney
- interface to DSL
- removable door
- interface to QRL

connection to magnet

DFBMA

- 5x6kA CLs
- service chimney
- removable door
- 12x120A CLs
Integration of current leads

- Current lead
- 50 K outlet
- 20 K supply
- 50 K collector
- Flexible hose/busbar
- Interconnect sleeve
- Busbar interconnect
- LHe level
- Level measurement
- Plug/lambda plate

DFB Project

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Tunnel integration of DFBAs

DFBAP
IR 8 right
Production & assembly scheme of a DFBA

Design & preparation
- Specifications & documents
- Reference drawings
- Detailed design of DFBA
- CL modules
- Shuffling module
- Components
- Instrumentsation
- Busbars & piping
- Plugs components
- Current leads
- Chimneys
- Superinsulation
- Cold supports
- Thermal screen
- Vacuum tank parts
- Non busbar piping
- Vacuum tank
- Thermal screen
- I beam
- Beam pipes system
- Busbars
- Shuffling box
- Raw materials
- Parts

Subassemblies
- CL cartridge
- Busbar system
- Preassembly of CL module
- Preassembly of SHM
- Preassembly of DFB

Modules assembly
- Assembly of CL modules
- Assembly of SHM modules
- Assembly of DFB

DFB assembly
- Finalization & installation
- Reception tests
- Transport
- Installation

Legend
- CERN
- Contractor at CERN
- Contractor at own premises

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Developments for the DFB project

Lambda Plates
DFBM type vacuum shell
Thermal tests for chimneys
Tests of cold foot

DFBM cryo prototype
Transport system for DFBAs

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Superconducting Links

• What
  – Space constraints in the LHC tunnel, cost and locally high risks associated with specific excavation works → adoption of the principle to employ superconducting power transmission lines (DSLs) in parts of the powering layout of the accelerator magnets.
  – The DSLs are essentially comprised of cryogenic, vacuum insulated, transfer lines housing one or more superconducting cables. DC currents will be in the range of 120 A to 6000 A. Nominal operation temperatures will be from 4.5 K to 6 K for the part which houses the cable, and about 70 K for the heat shielding.
Superconducting Links

• Where
  – Five DSLs will be needed. One of them will be exceptionally long, about 500 m in length without any intermediate branches. It will link the 3 km long continuous cryostat of accelerator magnets of Arc 3-4 of the LHC to a current feed box located in UJ33 some 500 m away. Besides its power transmission function, the link will also need to provide the cryogens for this current feed box. An additional four, significantly shorter, links will be used at points 1 and 5 of the LHC machine to bring power from current feed boxes to individual magnet cryostats (Q6, Q5 and Q4D2). Each of those four links will be about 70 m in length with two intermediate branches, roughly 3 m in length, to individual magnet cryostats.
Superconducting Links

pt1 & pt5

![Diagram of Superconducting Links with labels and connections.]

pt3

![Diagram of another part of the Superconducting Links system.]

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Configuration of the DSLs

Branch of a DSLA

Powering the DSLC

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Superconducting Links

• When (time window for installation)
  
  Before the magnets and DFBLS, avoiding QRL installation and commissioning

  DSLA: IP1L, RR13-UJ13………………Jan 2005
  DSLE: IP5R, RR57-UJ57………………April 2005
  DSLD: IP5L, RR53-UJ53………………May 2005
  DSLB: IP1R, RR17-UJ17………………Nov-Dec 2005
  DSLC: IP3, UJ33, UP33 & R34….Jan-Feb 2006
Superconducting Links

- How: transfer lines (DSL A, B, D, E)
Tunnel integration

• How: transfer lines (DSLc routing tunnel->trench-> UP33->DFBL)
Superconducting Links

• Challenges

  – *Time*
    • integration studies, interfaces, IT, December finance committee

  – *Manufacturing*
    • Quality of detailed design, and manufacturing

  – *In situ installation*
    • Long cable lengths to be inserted in the DSLs in the tunnel
Summary

Global approach of Cryomagnet powering
- DFB when possible
- DSL + DFB when impossible/inconvenient

Tunnel integration
- 3D integration studies

Situation: Technical solutions frozen, production of specification
Production of DFBs

Design input definition
Functional spec., etc.

Reference drawings
Specification drawings
detailed drawings
Parts manufacturing

Raw materials

Layouts

Components
Components

DFB Integration
Testing

Transport to CERN
Assembly & integration
Integration of current leads

Components
Subassemblies

End of production testing
Acceptance testing
Transport to tunnel
Tunnel installation
Tunnel testing

Commissioning

Operations at CERN

External supplier participation
Mostly CERN