“D1-DFM connection module” (DCM)

Review Report

28 April 2021

EDMS 2560776 v. 1.0

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This document reports the outcome of the “DCM Detailed Design Review” held on 15-16 April 2021 (Internal review of the D1 DFX connection module (15-16 April 2021) · Indico (cern.ch))

Introduction

The Review Scope, Mandate and Program were defined, by TE-MSC in agreement with HL-LHC Project, as follows:

Engineering Design Review of DCM of WP3 with a special session on cold diodes

Scope: review the engineering design of the DCM and the cold diodes with the purpose of:
1. Verifying the maturity of functional and technical specifications
2. Verifying whether the design is adequate to meet functional requirements and for the intended use of the equipment
3. Verifying the level of maturity of the design and qualification
4. Assessing the level of readiness for the procurement of critical items
5. Assessing the level of readiness for prototyping and production

Mandate of the review committee:
1) Review the functional and technical specifications and confirm its completeness in terms of cryogenic, mechanical and electrical requirements;
2) Review the engineering design wrt cryogenic and operational aspects and wrt to mechanical and electrical aspects, including interfaces;
3) Review the electrical joints and associated resistance, the robustness of the electrical insulation and the instrumentation applied to the diodes and their leads;
4) Review the integration and installation plan in the LHC machine and the compatibility of the DCM location wrt the tunnel environment and interfaces with other systems;
5) Check the conformity of the safety requirements for both cryogenic and electrical aspects and compatibility of safety equipment with tunnel environment;
6) Review plan and schedule for DCM cryostat and diodes production and assembly;
7) Review status of the MIP and its maturity for the procurement of the critical components

Review Committee: S. Atieh, K. Brodzinski, M. Modena (chair), D. Perini, A. Siemko.
Presentations:

- **Welcome**: A. Devred
- **DCM in WP3 & Masterplan**: Speaker: E. Todesco
- **Functional & Technical specification**: Speaker: Y. Leclercq
- **Work Breakdown Structure**: Speaker: F. Crisci
- **DCM Transport and Integration**: Speaker: P. Fessia
- **Engineering Detailed Design**: Speaker: Y. Leclercq
- **DCM Manufacturing & Inspection Plan**: Speaker: F. Crisci
- **DCM Prototyping and Production Plan**: Speaker: F. Savary
- **Press-pack and IT diodes**: Speaker: G. D’Angelo
- **Diodes stack**: Speaker: G. D’Angelo
- **Maintenance in the LHC Tunnel**: Speaker: S.C. Spathopoulos

Acknowledgement

The Review Panel would like to thank all the Speakers for the provided presentations very clear and detailed.

Executive Summary:

Context and main remarks:

The Review Panel would like to acknowledge the design advancement of this items that is the last element of the Cold Powering system that was subjects of several reviews in the last years. The DCM will be placed between the DFX and the D1 the first magnets of the series of magnets powers by the DFX and its Superconducting Link (DSHX).

Referring to the six **Review Mandate specifications**, the Review main conclusions and recommendations are here presented:

1) **“Review the functional specification and confirm its completeness in terms of cryogenic, mechanical and electrical requirements”**: The Functional specification presented and available in EDMS (2454318), seems clear and complete considering the main working parameters and requirements. Some design and operational aspects must be consolidated with HSE. The complying with PED whenever possible (reference to applied standards) should be stressed.

   ➔ **RECOMMENDATION N.1:**
   Verify with HSE (and HL-SO) the complying of the design and requirements with CERN and PED standards. HSE should be put as soon as possible in the loop for all elements/components that need a CERN qualification.

2) **“Review the detailed design wrt cryogenic design and operational aspects, mechanical design and interfaces, electrical design and interfaces”**: I. The developed mechanical, cryogenic and electrical design was presented. As also mentioned by A. Devred in the introduction, design can be considered in an “advanced engineering design phase”. Interfaces with other WPs and services seem correctly addressed. Thermomechanical design of the connection cryostat shall allow for safe independent cool down of the machine equipment on the left
and right side of the lambda plate (D1 cooled down while DFX kept warm and vice-versa). Differential thermal expansion/contraction should be checked for all possible thermal scenarios and implemented in the design.

II. As the connection cryostat is a dead-end cryogenic volume, it will be cooled down mainly via bus-bars conduction. The needed time of the cool down has to be estimated (plot a graph of lambda plate temperature vs. D1 temperature). If the lambda plate cool down delay is “considerable” (e.g. more than few hours), additional cool down/warm up line could be added between lambda plate region and D1 jumper to provide active lambda plate circulation in the cryostat.

**RECOMMENDATION N.2:**
Finalize the last open questions of the cryogenic and thermo-mechanic functional design. More precisely:
- Check thermo-mechanic behaviour of the system (e.g. differential thermal expansion/contraction) for all working scenarios.
- Evaluate the module extremity (on the lambda plate site) cooling time vs. D1 cooling time. If the evaluated delay is considered too long this will be a lost time for the machine operation (i.e. integrated luminosity). In that case the possibility to add a small cool down/warm up He line routed from the D1 jumper should be addressed and implemented.

III. The DCM will be connected with elements (D1) that will be remotely aligned via the new Full Remote Alignment System (FRAS). The actual max. range of relative displacement of the DCM wrt D1 is of ± 10mm. The FRAS alignment range is of (± 2.5mm). The two displacement ranges seems compatible. The DCM has anyway to be part of the detailed FRAS operation procedure to always check relative position of each FRAS element to monitor and avoid any risky movements.

**RECOMMENDATION N.3:**
Check with FRAS design team (Survey-BE/GM) if any design/control consideration shall be bring following the FRAS requirements impacting on D1 position.

IV. The design of the diode stack cryo-assembly in a full cantilever configuration seems not evident. The Panel is not convinced that the presented design is suitable to assemble it as a pre-assembled unit, in particular due to the weight of the diodes and thermal screen cantilever design without additional supports. It is strongly recommended to test the design in a fully representative mock-up. This will be even more important considering the eventuality of diodes replacement in the Tunnel environment.

**RECOMMENDATION N.4:**
Test the installation procedure of pre-assembled diode-cryostat on a fully representative mock-up, including the development of all needed tooling, also the tools necessary for the activities in the LHC Tunnel environment (limited space, ALARA requirements, etc.).

V. As recommended for other elements of the Cold Powering system, it would be a big advantage in work, money and time to try to harmonise as much as possible the dimensions of the edge welds (lip welds). This will allow the use of existing tools, assessments, and qualified welding and testing procedures.

**RECOMMENDATION N.5:**
Harmonise as much as possible the dimensions of the elements for the edge welds (lip welds) in order to profit from the development of similar LHC welding tools as well as the welding and testing procedures.
3) “Review the electrical joints and associated resistance, the robustness of the electrical insulation and the instrumentation applied to the diodes and their leads”:

I. The Diode Bus-bars (BB) connection concept presented is based only on soldering. This could be consolidated by adding some clamping elements. Consider to investigate this implementation. Alternatively, due to the short time constants of current decay, instead of soldered connection a well-designed bolted connection can be considered, which is also favourable due to the ALARA requirements.

II. A detail design of the guides for the BB was not present. This can be a critical aspect especially for regions like the diode elbow and the flexible hose at the connection with D1.

III. Instrumentation seems well sized and well designed. Nevertheless the Cernox sensor close to lambda plate should be doubled (spares not actively connected but available in case of failure of 1st one).

⇒ RECOMMENDATION N.6:
- Consider to revise the Diode stack BB connection adding to the design a clamping concept/elements. Alternatively, reconsider a well-designed bolted connection.
- Develop a detail design for all the BB guides with main attention to diode elbow and flexible hose regions. Try to push for standardization of these elements.
- Implement a spare Cernox sensor close to the lambda plate.

4) “Review the integration and installation plan in the LHC machine and the compatibility of the DCM location wrt the tunnel environment and interfaces with other systems”:

The DCM will be installed in very crowded regions of the IP1&5 LSS. The environmental layouts at the 4 location will be not identical, but it is planned to have a unique design for the DCM with a universal spare (already assembled).

⇒ RECOMMENDATION N.7:
- Check that the R-L symmetry of the installation and interfacing of other elements is fully compatible with a unique CDM design.
- Put in the loop M. Pojer (Mr. Polarity) in this analysis and for any aspect linked with the BB routing, polarity check, etc.
- Check carefully with WP15 Integration the specificity of the different installations wrt the support design and if some fixation points to the tunnel vault could be an advantage (exceptional maintenance tooling fixation, etc.).

5) “Check the conformity of the safety requirements for both cryogenic and electrical aspects and compatibility of safety equipment with tunnel environment”:

The DCM cryogenic volume could be seen as an “appendix” of the D1 volume, while the cryogenic volume and insulation vacuum wrt DFX will be separated by the lambda plate and a vacuum barrier. It is not yet assessed/decided the position and dimension of a quench relief valve and vacuum volume relief plate.
RECOMMENDATION N.8:
The He and vacuum vessels design must be completed (urgently) as concerning the safety devices. The positions of the quench relief valve and the vacuum volume relief plate should be optimized for the entire assembly D1-DCM-DFX. This work has to be done together with the CRG-SO, HL-SO and HSE.

6) “Review plan and schedule for DCM cryostat and diodes production and assembly”:
As for other elements of the Cold Powering system the priority of procurement and manufacturing is concerning the first unit that has to serve the String Facility. For the other units that will be installed in 2026 in the LHC Tunnel the manufacturing plan is less critical. It is not planned to wait the results of the prototype to launch the procurement and manufacturing of the series units. This is comprehensible for the procurement of the main components (e.g. for Vacuum and He vessels and for the thermal shield) but it must be envisaged the possibility to wait the results of the prototype test in the String before to start the assembly of the series units.

RECOMMENDATION N.9:
Envisage the possibility to wait for the results of the prototype test in the String Facility before to launch the assembly of the series units (in case of possible necessity of minor modifications).

7) “Review status of the MIP and its maturity for the procurement of the critical components”:
The MIP presented seems complete and covering all the critical aspects of the procurement and manufacturing. Nevertheless few points were highlighted:

RECOMMENDATION N.10:
- Provide a document that covers all electrical functional, qualification and testing aspects for the DCM (similar documents exist for the other main elements of the Cold Powering systems).
- As already mentioned, put M.Pojer (Mr.Polarity) in the loop for an external checks of the electrical routing and for finalization of documentation.
- Procurement of Austenitic SS components must be done imposing the respect of the CERN specification for such materials.
- Similar problem (as evidenced for the DFX and DFM procurement) concerns the Cobalt content in the SS. Face this aspect following a coherent approach and in close contact with HL-SO and HSE.
- For the bellow design and procurement profit from the expertise of C. Garion.
- A pressure test of DCM unit is planned as a type test. Before the prototype installation in the String it is recommended to add an 80K thermal cycle test with continuous electrical monitoring of BB dielectric insulation followed by He leak tightness test.

The Review Panel 28 April 2021