Update on Magnet Circuits Configuration

F. Rodriguez Mateos

TCC July 7 2016

Outline

- The main recommendations from the Magnet Circuits Review in March 2016
- The main aspects of the re-baselining in June 2016
- The follow-up given to the main recommendations
- The Magnet Circuits Forum

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Conceptual Design Review of the Magnet Circuits for the HL-LHC:

- 21-23 March, 2016 -

Review Report

presented by

Akira Yamamoto

on behalf of the Review Panel members

Guram Chlachidze (Fermilab), Arnaud Devred (ITER), Chen-Yu Gung (ITER),
Rudiger Schmidt (CERN), Davide Tommasini (CERN),
Akira Yamamoto (KEK and CERN, Chair), and Markus Zerlaunth (CERN, Sc. Secretary)

Reported at HL-LHC Technical Coordination Committee, 31 March, 2016

Recommendations per circuit type (1/2)

11 T

Numbe	System	Recommendation
#1	11T	trim-PC versus orbit correctors to be considered
#2	11T	current leads for trim PC to be provided
#3	11T	quench detection issues (variable threshold, variable delays)
#4	11T	improve QH reliability

Inner Triplet

Numbe	System	Recommendation
#5	IT	beam dynamics justification before ECR for one single circuit
#6	IT	comparison different basic quench protection options
#7	IT	assessment of long term reliability of CLIQ
#8	IT	inner and inter layer QH R&D
#9	IT	risk analysis, failure modes
#16	IT	high-current 2-quadrant PC development
#17	IT	compatibility CLIQ technology with Nb3Sn magnets

Recommendations per circuit type (2/2)

D2

Numbe	System	Recommendation
#10	D2	D2 quench protection analysis

IT correctors

Numbe	System	Recommendation
#11	IT-C	energy extraction vs QH
#12	IT-C	HO (>2) lower operational current to below 120A

All circuits

Numbe	System	Recommendation
#13	all	protection of CL connected to circuit
#14	all	protection of link connected to circuit
#15	all	protection of bus bars connected to circuit
#20	all	reinforce quantitative analysis of dependability at entire protection level
#25	all	consideration of the new discharge time constants (characteristic times) for s.c. link
#26	all	consider high current separators at the level of the current leads

Recommendations for specific elements/activities

ElQA

Numbe	System	Recommendation
#18	ElQA	reconsideration of test voltage definitions
#19	ElQA	assess conditions under which worst case voltages appear and adequate test conditions

HDS

Numbe	System	Recommendation
#24	HDS	reduce triggering time from the present 4 ms down to 1 ms

Recommendations on general aspects

STRING

Numbe	System	Recommendation
#21	STR	test programme to be defined with objectives
#22	STR	ultimate safety test - complete powering failure

Plan, Schedule and Documentation

Numbe	System	Recommendation
#23	PSD	resource loaded planning
#27	PSD	close and regular interaction between involved experts and WP

ECR
after review

HL – LHC Engineering Change Request
CHANGES IN CIRCUIT BASELINE AFTER THE CONCEPTUAL REVIEW HELD IN MARCH 2016

ECR DESCRIPTION

WP Originator	WG Magnet Circuits Coordination	***Process***	-
Equipment	Circuits Baseline	***Baseline affected***	Scope, Cost
Drawing	-	***Date of Issue***	2016-04-26
Document	TDR v0	***CI responsible***	F. Rodriguez Mateos
WPs Affected	WP2, WP3, WP6a, WP6b, WP7, WP11, WP15, WP17	***Reference Document***	TDR Version 0.0

Detailed Description

The High Luminosity LHC (HL-LHC) Project requires replacing or modifying numerous superconducting magnet circuits in the High Luminosity insertions (Point 1 and Point 5) of the collider. The higher peak fields, higher currents and larger magnetic energies, as well as the necessity to relocate the power converters afar from radiation areas, with the use of superconducting links, make the system more complex and technically very challenging. The role of "Mr. HL-LHC Circuit" was appointed to steer the optimization and ensure consistency of the whole system.

The Conceptual Design Review of the Magnet Circuits for the HL-LHC (https://indico.cern.ch/e/477759) took place from 21st to 23rd March 2016. This ECR contains the changes proposed after the Review for approval by WPLs and PL during TCC.

Reasons for change

The proposed simplifications are in line with the recommendations from the Review Panel. See presentations from https://indico.cern.ch/e/477759

Impact on Cost, Schedule & Performance

The impact on cost will be evaluated by the Project Budged Officer (add after link to the memo)

Impact on other items within the WP

Not applicable.

Impact on other WPs

Several WPs are requested to give comments on possible impacts. See presentations https://indico.cern.ch/e/477759

Actions to be carried out if ECR is accepted

1) Reduction in the number of main inner triplet circuits from 2 to 1 per IP side.
   - This single circuit will have no energy extraction system
   - One, 2-quadrant converter is required per circuit, rated 18 kA
   - A new trim circuit is required on Q3 with a rated current of 2 kA.
2) Orbit correctors next to D2 and Q4 will not require quench heaters, the option using energy extraction is being considered and therefore should be kept open.
3) Orbit correctors next to Q5 will not require quench heaters.
4) New current levels are defined for the the inner triplet's superferric correctors of orders 3, 4, 5, and 6 (normal and skew): the new rated currents are 120 A instead of 200 A previously.
5) Time constants for the circuits under fast discharge (also known as characteristic times) are given in annexed table.

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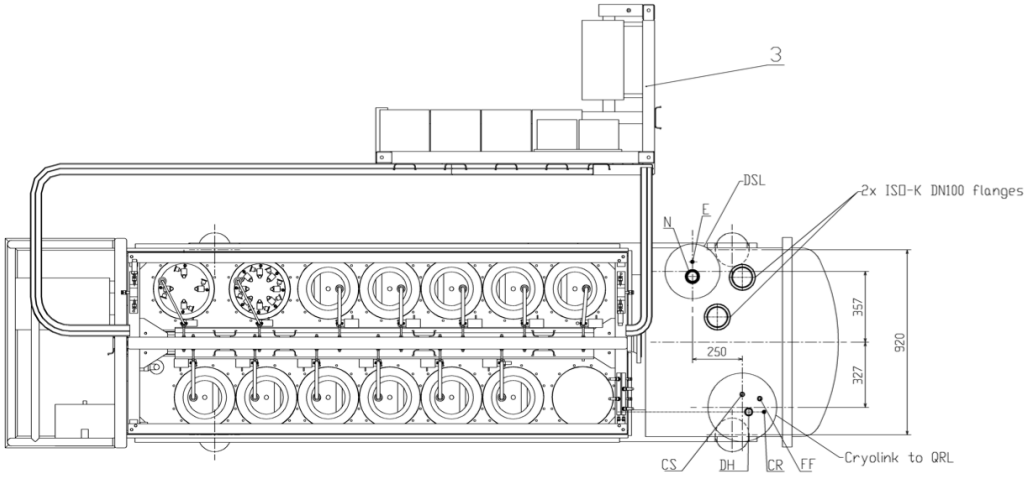
Outcome of June 2016 «crises exercise»
from Lucio's talk at TCC on June 23 2016

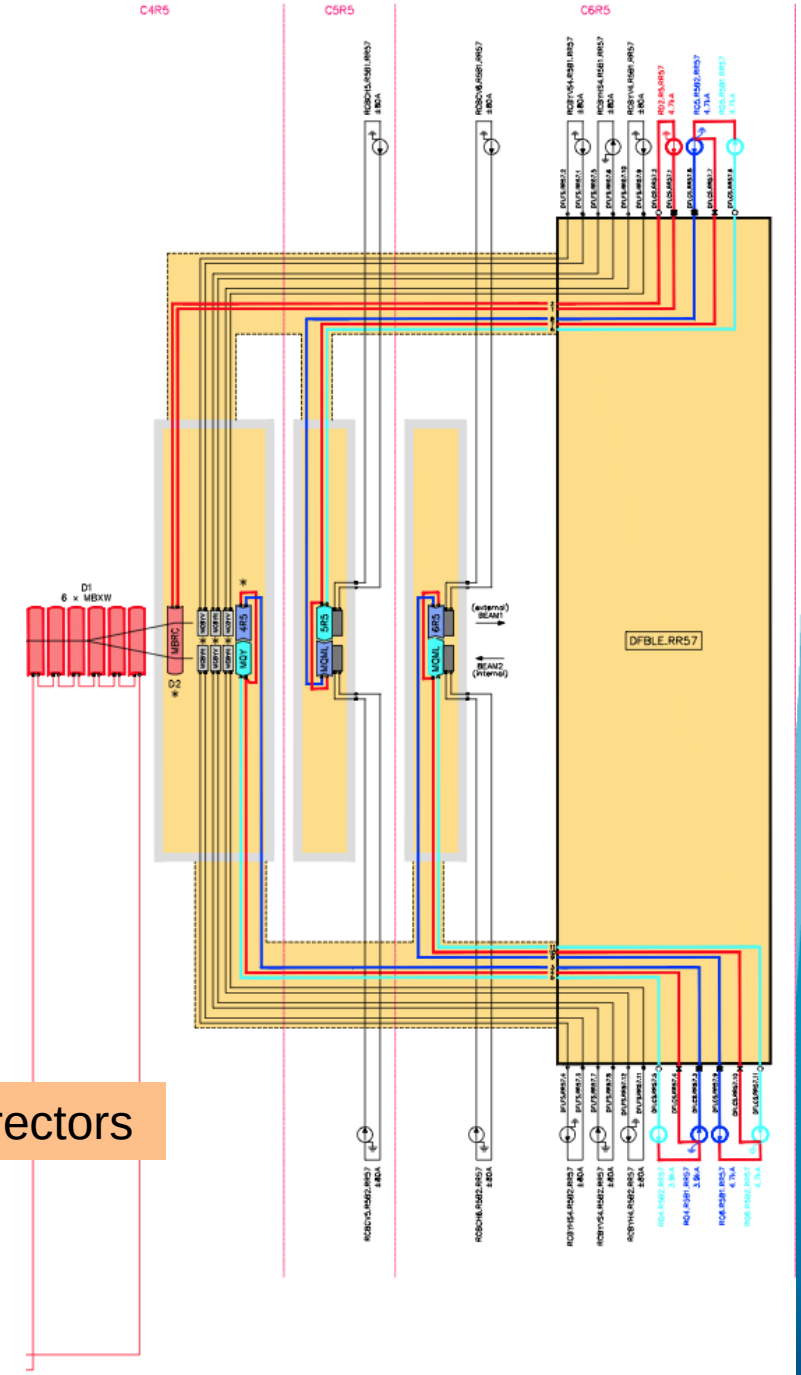
- Staging installation of new MQYY as new Q4 (90 mm aperture) to after HL-LHC end (i.e in LS4), *if needed*, mantaining present 70 mm MQY, i.e. Q4 modified for 1.9 K operation.
- QPS for the MQXF maintaining all systems (QH_{out}, Qh_{inn}, (Qh_{intr}), and CLIQ) however with a minimal configuration **with redundancy**.
  - Integration of CLIQ in LHC UL
- Powering the IPQs (Q6-Q5-Q4) from the RR, via existing EPCs, DFBLs (and links?)…

Q6 remains as is in LHC now
Q5 will be the present Q4
Q4 will be an MQY @ 1.9 K + 4 correctors/beam

DFBL:
- 11 CL 6 kA
- 12 CL 120 A

DSL is constituted of:
- 12 cables of 6 kA
- 12 cables of 600 A





Today there are 8 DCF leads to power locally correctors

Infos from L Tavian, H Prin and P Fessia

Circuits Table after Review with re-Baseline

	Circuits for HiLumi	Magnet Type	Number of circuits per IP Side	Number of circuits	I_nominal [kA]	I_ultimate [kA]	I_rated [kA]	L per circuit [mH]	Quench Heaters	CLIQ	EE	characteristic time [s]
Inner Triplet	Triplet Q1, Q2a, Q2b, Q3	MQXFA / MQFXB	1	4	16.5	17.8	18.0	255	Baseline (inner/outer layer)	Baseline	no	0.1-0.5
	Trim Q1				2		2.0					
	Trim Q3				2		2.0					
	Trim Q2a				0.12		2.0					
	Orbit correctors Q2a/b MS vertical	MCBXFBV	2	8	1.6	1.73	2.00	18	Baseline	no	Option	0.1-0.5
	Orbit correctors Q2a/b MS horizontal	MCBXFBH	2	8	1.47	1.59	2.00	29	Baseline	no	Option	0.1-0.5
	Orbit correctors CP MS vertical	MCBXFAV	1	4	1.6	1.73	2.00	33	Baseline	no	Option	0.1-0.5
	Orbit correctors CP MS horizontal	MCBXFAH	1	4	1.47	1.59	2.00	53	Baseline	no	Option	0.1-0.5
	Superferric, order 2	MQSXF	1	4	0.182	0.20	0.20	1247	no	no	Option	7.57
	Superferric, order 3, normal and skew	MCSXF / MCSSXF	2	8	0.105	0.11	0.12	186	no	no	PC crowbar	0.41
	Superferric, order 4, normal and skew	MCOXF / MCOSXF	2	8	0.105	0.11	0.12	200	no	no	PC crowbar	0.41
	Superferric, order 5, normal and skew	MCDXF / MCDSXF	2	8	0.105	0.11	0.12	187	no	no	PC crowbar	0.53
	Superferric, order 6	MCTXF	1	4	0.105	0.11	0.12	576	no	no	PC crowbar	0.37
	Superferric, order 6, skew	MCTSXF	1	4	0.105	0.11	0.12	126	no	no	PC crowbar	0.80
D1	Separation dipole D1; MBXF	MBXF	1	4	12	13.0	13.0	25	Baseline	Option	no	0.1-0.5
D2	Separation dipole D2; MBRD	MBRD	1	4	12	13.0	13.0	27	Baseline	Option	no	0.1-0.5
	Orbit correctors D2	MCBRD	4	16	0.5	0.54	0.6	600	no	no	Option	10.0
Q4	Large aperture 2-in-1 Quad; Q4	MQY	2	8	4.50	4.9	6.0	74.0	Baseline	no	no	0.1-0.5
	Orbit correctors Q4	MCBY	8	32	0.072	0.08	0.12	5270	no	no	no	10.0
Q5[1]	Present LHC Q4 magnet	MQY	2	8	4.51	4.9	6.0	148.0	Baseline	no	no	0.1-0.5
	Orbit correctors present Q4	MCBY	6	24	0.072	0.08	0.12	5270	no	no	no	0.4
Q6	Insertion Quad, 2-in-1 aperture; Q6	MQML	2	8	4.31	4.7	6.0	21.0	Baseline	no	no	01.-0.5
	Orbit correctors Q6	MCBC	2	16	0.08	0.09	0.12	2840	no	no	no	0.2
11T	11T dipole, MBH	11T dipole, MBH	1	2	11.85	12.798	13	127.0	Baseline	Option	existing RB EE	as RB
	Trim circuit				0	0.034	-0.3 / 0.1					

D. Wollmann

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Follow up given to the Review's recommendations

- Further analysis of normal and failure scenarios on QXF circuit, confirmation of the baseline scheme
  - Analysis of CLIQ leads sections
  - Analysis of CLIQ currents
  - Interaction with link as well as implications to bus bars and current leads remain to be discussed (in the agenda for the second meeting of the MCForum)
- Reconsideration of the strategies for high voltage withstand levels
  - Agreement reached with LARP for QXF
- Opening a development line for bipolar energy extraction systems in the 2kA range
  - Heaters vs energy extraction in correctors programmed for first meeting of MCForum
- Development of quench detectors is advancing well
- A detailed model for CLIQ failure analysis has been developed and is giving first results
- Trying to gain as much experience with CLIQ as possible (recent commissioning of two units at FNAL)
- Organization of a Forum to deal with all aspects of circuits related to powering and protection
- And much more …

Recent work

- Two complete and recent presentations :
  - CLIQ : space requirements and circuit protection - https://indico.cern.ch/event/544204/
    - Re-baselining Meeting, June 17, 2016
  - HL-LHC WP7: Machine Protection and Availability - https://indico.cern.ch/event/546270/
    - TE-TM, June 28, 2016
  - HVWL WG efforts gave first agreement for QXF magnets:

Agreed upon

Circuit Element	Expected Vmax [V]	V hi-pot	I hi-pot [µA]	Minimum time duration [s]
Coil to Ground at RT *	n.a.	3 kV	10	30
Coil to Quench Heater at RT *	n.a.	3 kV	10	30
Coil to Ground at cold **	520	1.5 kV	10	30
Coil to Quench Heater at cold **	900	2.3 kV	10	30

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One of the recommendations of the recent review on HL-LHC Magnet Circuits was:

"… to realize close and regular interaction (communication) between the involved experts and work-packages. This could be possibly done by setting-up of a dedicated working group or by using existing structures to discuss circuit integration and protection on a regular basis and to identify the optimum scheme for each magnet circuit system."

(*Draft*) Mandate – to be approved by HL-LHC Project Leader

- Within the framework of the HL-LHC Circuits Coordinator (Mr Circuit), the mandate for the new Magnet Circuits Forum (MCF) is as follows:
  - The Forum is the meeting where all aspects related to powering and protection are discussed, in particular the ones pertaining to the optimization of circuit layouts and definition of protection means
  - Subjects in the agenda are defined in close collaboration with the relevant WPs
  - Interface aspects between systems are clarified through meetings at the Forum. To this end, a documentation plan has to be developed and completed. The aim is to prepare a set of functional interface specifications that can be used as input for the design (technical specifications) of the different systems
  - Assessment on realistic failure scenarios and required mitigation strategies on a global basis is part of the activities of the Forum
  - The Forum is the meeting where aspects related to high voltage withstand levels are discussed and harmonized
  - The Forum reports regularly to TCC and takes up any relevant discussion within the domain of cold/warm powering and protection of the HL-LHC circuits in collaboration with the relevant WPs

- Two participants have been nominated by the Work Package Leaders.
- WP Leaders and Deputies as well as Group Leaders receive invitations ex-officio and are invited to attend at their own discretion depending on the agenda.
- Leaders of involved Groups have endorsed the membership and in some cases proposed additional names.
- First meeting has been organized for July 12th, the second for July 26th.
- Meetings will be organized on a 2-week basis.

Membership

Work Packages	WP Leader	Deputy WP Leader	HL-MC Forum Member 1	HL-MC Forum Member 2
WP2	Gianluigi Arduini	Rogelio Tomas Garcia	Massimo Giovannozzi	Riccardo De Maria
WP3	Ezio Todesco	Paolo Ferracin	Juan Carlos Perez	Susana Izquierdo Bermudez
WP6a	Amalia Ballarino	Vittorio Parma	Patrick Retz	Amalia Ballarino Vittorio Parma
WP6b	Jean-Paul Burnet	Michele Martino	Michele Martino	Hugues Thiesen
WP7	Daniel Wollmann	Reiner Denz	Arjan Verweij	Jens Steckert
WP9	Serge Claudet	Rob Van Weelderen	Rob Van Weelderen	Juan Casas-Cubillos
WP11	Frederic Savary	Herve Prin	Arnaud Foussat	Ludovic Grand-Clement
WP15	Paolo Fessia		Paolo Fessia	-
WP16	Marta Bajko Mirko Pojer		-	-
WP17	Laurent Tavian	Beniamino Di Girolamo	-	-

Chair and Scientific Secretaries:
Felix Rodriguez Mateos
Hugo Bajas
Samer Yammine

Representation from MP3:
Arjan Verweij
Daniel Wollmann

Representation from ELQA:
Mateusz Bednarek
Giorgio D'angelo

For info list:
Lucio Rossi
Oliver Bruning
Andrzej Siemko
Luca Bottura
Dimitri Delikaris
Mike Lamont
Rudiger Schmidt
Markus Zerlauth
Jean-Philippe Tock

Many thanks for your attention!