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Powering of Q5 in IR6 to ultimate current

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On behalf of OP, MP3 and HL-LHC WP2

56th HL-LHC TCC

From Layout database

RQ5.L6 : Matching section individually powered Quadrupole Link to MTF

ID : 184909, Circuit version : STUDY, Layout version : STUDY

Power Converters in the Circuit	PC Location	Rack Name/Slot
RPHH.UA63.RQ5.L6B1 (MTF, TE-EPC Database)	UA63/GA	
RPHH.UA63.RQ5.L6B2 (MTF, TE-EPC Database)	UA63/GA	
Magnets in the Circuit	**Number**	
MQY	2	
Current Leads in the Circuit		
DFLCS.A5L6.1		
DFLCS.A5L6.2		
DFLCS.A5L6.3		

Short sample current @ 4.5 K = 4440 A

Magnets per Power Converter

RPHH.UA63.RQ5.L6B1

MQY 1

I Nominal :	3610 A	I Ultimate :	3900 A		
I Offset :	.0 A	I Overload :	1.03 * I ultimate A	I Min Op :	80.0 A
L tot :	.074 H	R tot :	.000843 Ohm	R tot Measured :	.000389 Ohm
Ramp Time :	360.00 s	max(di/dt) :	10.833 A/s	Time Constant :	87.587 s
U leads :	.120 V	U Extr :	.000 V		
U Boost :	.799 V	U Coil :	3.370 V	U Peak Circ :	4.170 V
Warm Cable Verification :	✔				

81.3% SS

RPHH.UA63.RQ5.L6B2

MQY 1

I Nominal :	3610 A	I Ultimate :	3900 A		
I Offset :	.0 A	I Overload :	1.03 * I ultimate A	I Min Op :	80.0 A
L tot :	.074 H	R tot :	.000843 Ohm	R tot Measured :	.000400 Ohm
Ramp Time :	360.00 s	max(di/dt) :	10.833 A/s	Time Constant :	87.587 s

N.B. The *nominal* current for each circuit which is contained in the Design Report or Layout Database is a “hardware-related” value which has no direct relation with the optics used in the machine. It matches the current needed for 7 or 7.5 TeV for the dipoles (fixed ring geometry) and main quadrupole (fixed cell optics), but it might be much different for the matching quadrupoles (variable insertion optics).
--> In the following I will use “**layout**” for currents contained in the two databases above and “**nominal**” for the current values needed for the ATS optics configurations.

Current needs for Q5.L/R6

* Currents include
  50 A as a stability margin

- 7 TeV
  - Taking all possible sets of ATS optics which are developed for LHC for 7 TeV (S. Fartoukh) and converting them in currents with the magnetic models (P. Hagen), we get for the four circuits:

Circuit	I_nom[A]	I_lay@7 [A]	Difference
RQ5.L6B1	3910	3610	-300
RQ5.L6B2	3742	3610	-132
RQ5.R6B1	3543	3610	167
RQ5.R6B2	3410	3610	200

- 7.5 TeV
  - From all possible optics and configurations for HL-LHC@7.5 TeV (R. De Maria), not necessarily corresponding to the the previous one, and converting them in currents, we get for the four circuits:

HLLHCV1.4

Circuit	I_nom[A]	I_lay@7.5 [A]	Difference	I_nom@7TeV [A]	Difference
RQ5.L6B1	4025.6	3900	-125.6	3754.6	145.4
RQ5.L6B2	**4205.9**	3900	**-305.9**	3928.2	-28.2
RQ5.R6B1	3977.3	3900	-77.3	3708.3	191.7
RQ5.R6B2	3940.4	3900	-40.4	3673.3	226.7

https://indico.cern.ch/event/750135/contributions/3104578/attachments/1702836/2742909/HL14-WP2-2.pptx

Hardware feasibility

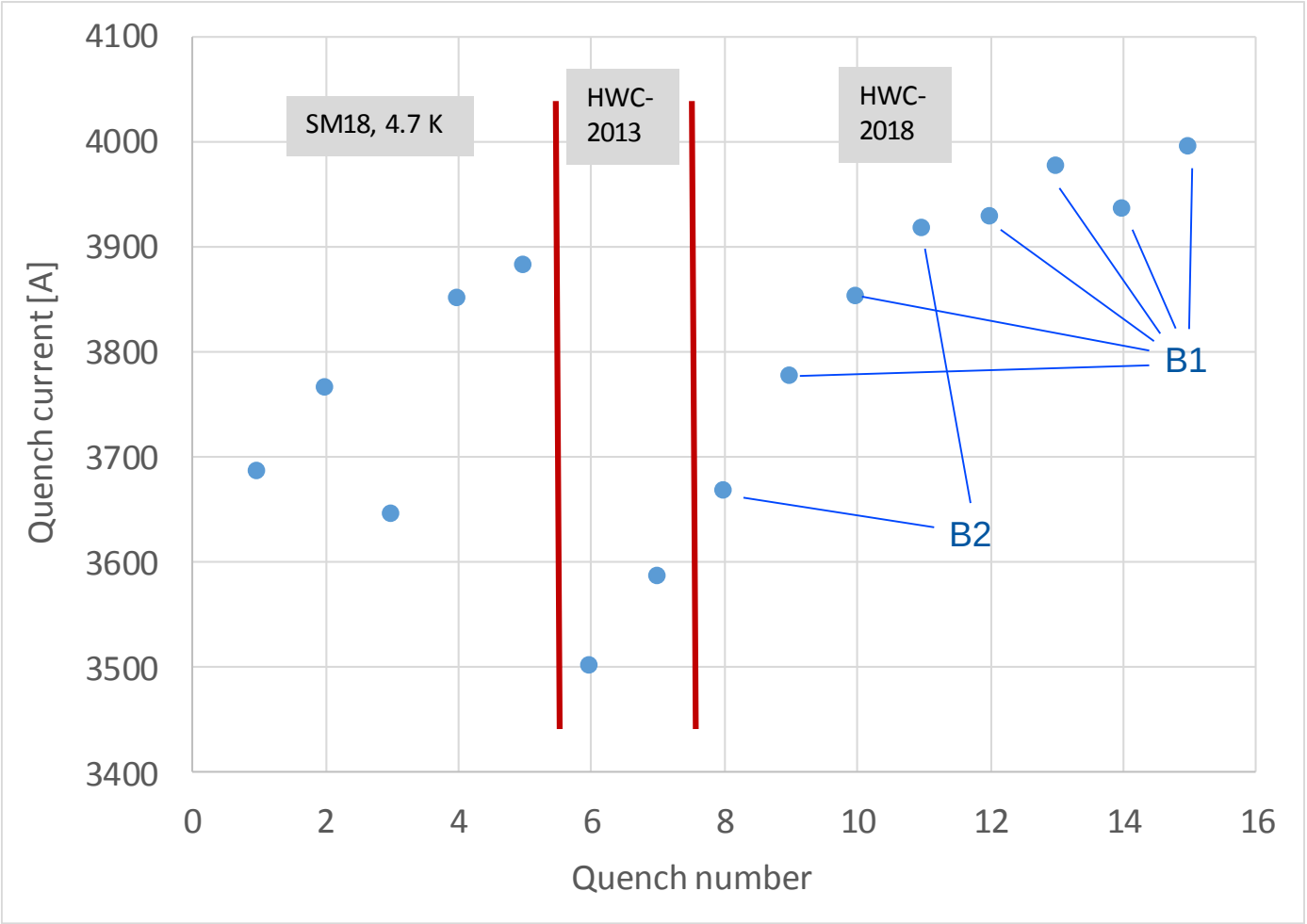
- PC-power part (V. Montabonnet)
  - For the RQ5.L6 circuit, the PC is a RPHH type, equipped with 3 * 2kA sub-converters and a 4 kA DCCT
  - ➢ No problem from power side, being able to reach 6 kA

- PC-DCCT (G. Hudson and M. Martino)
  - The specifications of the 4 kA DCCTs are as follows:
    - 105% of nominal: continuous operation (accuracy/precision performance should be “nominal”)
    - 110% of nominal: 5 seconds operation
  - ➢ “So, as your tests will be at 105%, the time at 4.2kA is unlimited”

- Cables (J.C. Guillaume)
  - “L'intensité max est de 3.9 kA. La longueur du circuit est de 44m. La section est de 1000mm2; ce qui laisse un peu de marge pour aller plus haut. Il faudrait vérifier les aspects chute de tension et débit d'eau avant de passer à 6 kA le cas échéant et faire une ECR”
  - ➢ No problems to operate to 4.2 kA

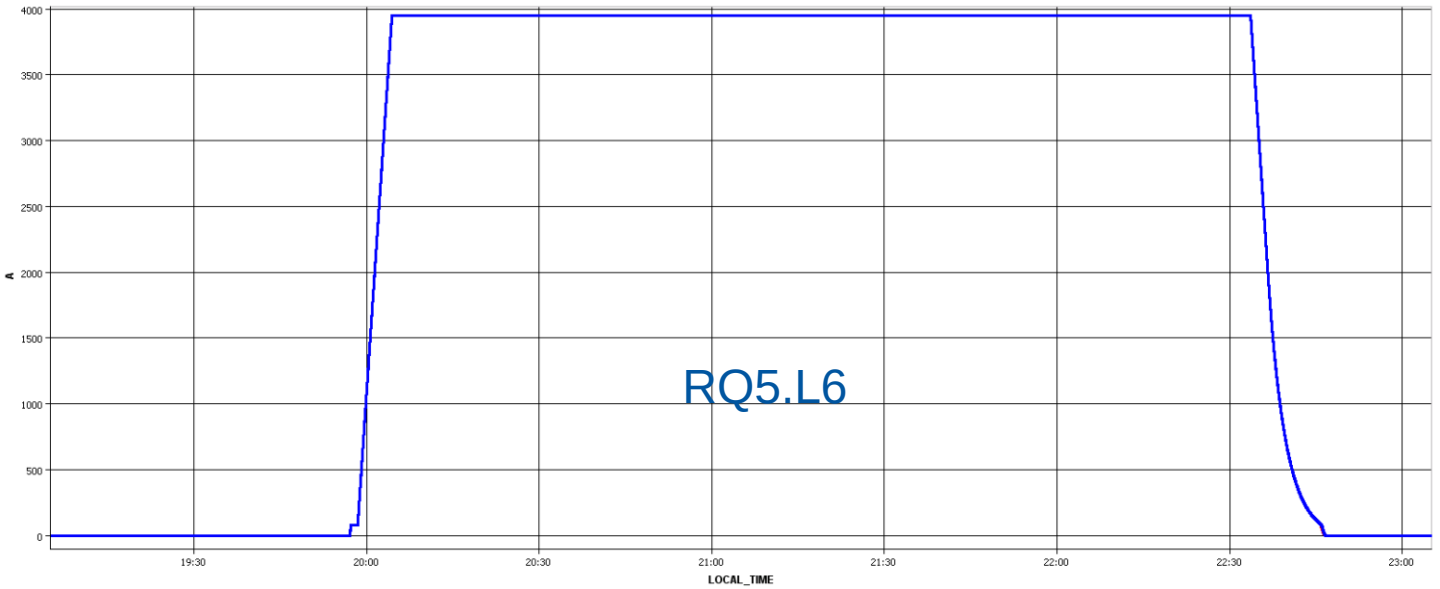
Quench behaviour

- A *controlled* quench campaign was performed during YETS 17/18



“Heat run”

- Commissioning completed with a cycle to 3950 A and a plateau of 2 ½ h
- **No limitation on this circuit for 7 TeV operation!!**



Conclusions

- RQ5.L6 was successfully powered to the layout ultimate current during the YETS17/18, with a limited number of quenches

- Current values close to the ultimate layout currents will be needed for operation at 7 TeV
  - From the tests performed, this seems to be feasible without any upgrade

- To operate at 7.5 TeV, currents above 90-95% of the SS will be needed without optics modification
  - Not much space is left for a stable and reliable operation of Q5.L6, above all in case of losses during dump; for Q5.R6, operation at 7.5 TeV should be possible without any upgrade.

- An identical test will be done on RQ5.R6 as the one done on RQ5.L6, during the end of run powering tests.

Thank you for the attention!

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