Electrical Qualification of WP6a Splices MgB_2-Nb-Ti

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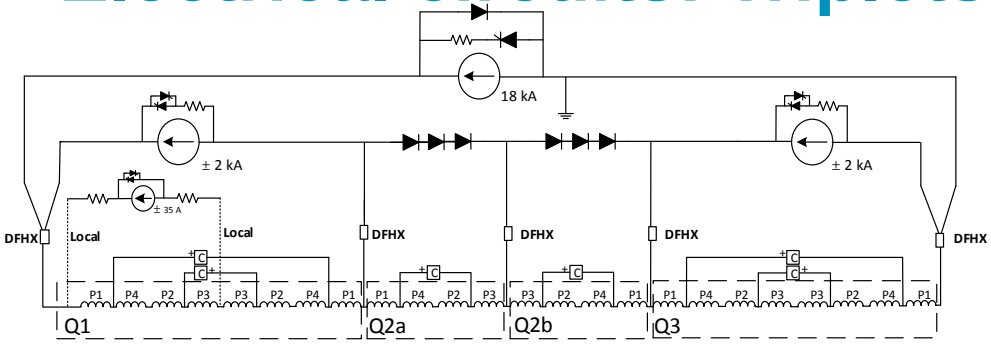
DFX Conceptual Design Review, CERN, 31/01/2019

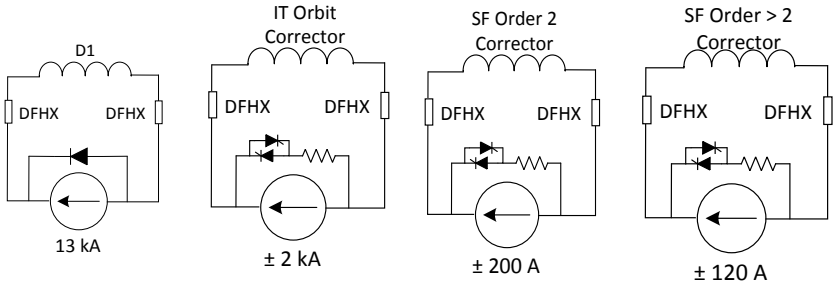
Electrical circuits: Triplets



One main 18 kA circuit
Three Trims:
2×2 kA (Q1 and Q3)
1×0.035 kA (Q1a)

Baseline established in May 2017

In addition: D1, Orbit Correctors and Higher Order Correctors individually powered



Current rating – Number of cables/splices

EDMS 1821907

	Magnet	Cold Powering			
	I_{ult}(kA)	I_{peak}(kA)	I_{lead} (kA)	I_{cable}(kA)	N_{leads}/N_{cables}
MQXF	17.82	-	18	18	2
Trim Q1	2	2.4	2*	7	1
Q2a/Q2b	Protec.	5.6	2*	7	1
Trim Q3	2	6.8	2*	7	1
MCBXFB	1.73	-	2	2	2+2
MCBXFB	1.59	-	2	2	2+2
MCBXFA	1.73	-	2	2	2
MCBXFA	1.59	-	2	2	2
D1	12.96	-	18	18	2

4× 18 kA
3× 7 kA
12 × 2 kA

Circuits characteristics

EDMS 1821907

Rating (kA)	MIITs ($MA^2 \cdot s$)	dI/dt (kA/s)	τ_n (no quench of magnets) (s)	τ_Q (quench of magnets) (s)	Equivalent time (s)
18 (*)	32	250	130	0.2	0.1
7	5	250	130	0.2	0.12
2 (**)	1	20	20	0.5	-
0.2 (***)	0.02	0.25	21	0.8	-
0.12	0.02	0.22	5	0.8	-

Table 3: Characteristics of magnets'circuits during transient operations. All reported values (dI/dt, MIITs and time constants) are based on simulations [1] [2] and are conservative. For different circuits with the same current rating, the most conservative values are indicated. For D1 a quench load identical to that of the MQXF main circuit is adopted (*). A characteristic time of 0.5 s for MIITs calculation and 0.1 s for dI/dt (**) are assumed. An energy extraction resistance of 1.5 Ω is introduced in the MQSXF quadrupole corrector circuit (***).

Protection strategy and transient analysis

Quench of SC Link

Cu braid around each composite strand

T0=25 K

Rating (kA)	ACu (mm^2)	MIITs	Tmax
18*	200	15+32	57
2**	34	15+1	34
2 (7)***	36	15+5	35

Significant increase in Cu stabilizer according to recommendations from circuits review. In the table the final cross section implemented is reported

Electrical insulation test

EDMS 1821907

Rating (kA)	Worst case voltage to ground during operation (V)	Acceptance tests of components to ground (V)		Insulation test voltage of system to ground (V)		Leakage current per component (µA)	Test duration (s)
		RT	NOC	RT	NOC		
18	900	4600	2300	460	1080	≤10	30
7	900	4600	2300	460	1080	≤10	30
2	540	3160	1580	316	648	≤10	30
0.2	540	3160	1580	316	648	≤10	30
0.12	40	1160	580	220	360	≤10	30
0.035	900	4600	2300	460	1080	≤10	30

Table 4: Test voltage of leads and cables and calculated highest voltage to ground during operation. For the 18 kA and 7 kA cables, the highest voltage is estimated to be 700 V (across the high resistance of Q1a trim) + 100 V (sum of voltages across crowbar and cables resistances) + 100 V (superconducting cable in the link resistive along the full length). For the 2 kA and 0.2 kA cables, an energy extraction of 500 V is considered (worst case scenario). For the 0.12 kA circuits the crowbar voltage across the power converter is taken into account for the calculations.

Electrical insulation tests

Ex. For MgB_2 cables

HV on-line RT tests during cabling (each MgB2 cable) at the manufacturer site
HV final test in He gas at RT at the manufacturer site
HV final test in He gas at RT at CERN
HV final test in nominal conditions at CERN (series test at CERN)

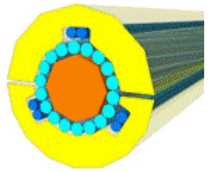
Sequence of electrical tests at different phases during installation in the tunnel (at RT)

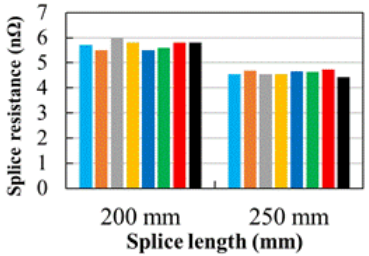
Splices – MgB_2 to Nb-Ti

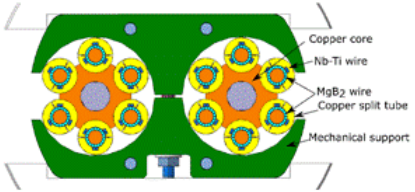
- MgB_2 wires ex-situ 1 mm diameter
  - 37 filaments with Nb barriers in a Ni matrix
  - 200 µm thick Monel sheath
  - 20 µm copper layer with Staybright coating

- Each of the 3 kA strands of 18 kA cable spliced to six Nb-Ti wire
  - Soldered with Sn-Pb
  - Splice provides continuity of cross section of stabilizer
  - Promote homogeneous current sharing
  - Expected and measured (FRESCA) resistance of 5.7 nΩ (200 mm long splice)
  - Scale with length as expected
  - Splice resistance constant vs. Temp.

- The six 3 kA splice are then spliced together with Sn-In
- **Expected resistance of the 18 kA MgB_2/NbTi splice :0.9 nΩ**







MgB_2/NbTi
Splice of DEMO1

Demo 1

Demo 1 measurements at 18.5 kA – 17 K

- **Ramp to 18.5 kA at 20 A/s**
- Plateau of 10 mins
- Stable on plateau, no voltage drift
- Total resist. of Link circuit in line with expectation: **~5 nΩ**
  - Two MgB_2/NbTi splices:~ **2x 1 nΩ**
  - MgB_2/MgB_2 splices:~ **1.5 nΩ**
  - Two NbTi/NbTi splices: **1x 0.4 and 1x 0.7 nΩ**