



Power Converters for Super-FRS Magnet Test Facility at CERN

E. Coulot – H. Thiesen, CERN TE-EPC-MPC





- SuperFRS test facility
- Power converter cluster
- Status of the power converters
- Conclusion



The test facility has been designed to test at cold at CERN the SuperFRS superconducting magnets.

59 cryostats will be measured before to be installed at FAIR at GSI.

number	cryostat type	mass cold/total	stored energy	pole field	current
28 23 8	dipole multiplet 1 multiplet 2	2 t/50t 45t/60t 35t/60t	0.5 MJ 1.5 MJ 1 MJ	1.6 T 2.5 T 2.5 T	~ 230 A ~ 300 A ~ 230 A
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- 2 types of cryostats:
 - Dipole cryostats:
 - Only one dipole magnet inside the cryostats (no correctors)
 - Multiplets cryostats:
 - Quadrupole and corrector magnets are integrated inside the multiplets
 - Different multiplets configurations with a maximum of 9 magnets:
 - 3 quadrupoles
 - 6 correctors (S, O and D magnets)



Example of multiplet (FHF1YMQ11)

9 power converters are needed to test the SuperFRS magnets



- The SuperFRS test facility is composed by:
 - 3 test stations
 - 1 power converter cluster (9 power converters)







- The selection of the test stations is done by electrical switches
 - 1 input (connected to the power converter)
 - 3 outputs (one output for each test station)







- 2 types of magnets
 - Main magnets (D and Q) with large inductance
 - Corrector magnets with low inductance

Magnet	EE	L	r_cable*	Tau	l_inj l	_nom	I_ult	E_nom	E_ult	Rise Time	U_boost U	_max_ult	
type	system	[H]	[Ohm]	[s]	[A]	[A]	[A]	[M]]	[MJ]	[s]	[V]	[V]	Proposed PC
D2	1 kV	17.362	0.015	1157	23	232	278.4	0.467	0.673	100	40.280	44.456	[±500A/±120V]
D3	1 kV	15.380	0.015	1025	23	232	278.4	0.414	0.596	100	35.682	39.858	[±500A/±120V]
D4	1 kV	32.344	0.015	2156	22	227	272.4	0.833	1.200	100	73.421	77.507	[±500A/±120V]
Q3	1 kV	25.360	0.015	1691	29	292	350.4	1.081	1.557	100	74.051	79.307	[±500A/±120V]
Q4	1 kV	38.040	0.015	2536	29	292	350.4	1.622	2.335	100	111.077	116.333	[±500A/±120V]
Q5	1 kV	25.360	0.015	1691	29	292	350.4	1.081	1.557	100	74.051	79.307	[±500A/±120V]
Q6	1 kV	38.040	0.015	2536	29	292	350.4	1.622	2.335	100	111.077	116.333	[±500A/±120V]
Q7	1 kV	21.547	0.015	1436	30	300	360	0.970	1.396	100	64.641	70.041	[±500A/±120V]
Q8	1 kV	32.320	0.015	2155	30	300	360	1.454	2.094	100	96.960	102.360	[±500A/±120V]
S	non	1.776	0.015	118	17	171	205.2	0.026	0.037	100	3.037	6.115	[±600A/±40V]
0	non	0.031	0.015	2	30	300	360	0.001	0.002	100	0.093	5.493	[±600A/±40V]
D	non	0.044	0.015	3	30	300	360	0.002	0.003	100	0.132	5.532	[±600A/±40V]



Power converter cluster

- GSI
- To limit the cost of the project TE-EPC has chosen standard power converters
 - 6 x [±600A/±40V] LHC power converters for the corrector magnets
 - 3 x [±500A/±120V] COMET-2P power converters for the main magnets (D & Q)
- TE-EPC is also responsible for
 - 9 x 600 A electrical switches
 - 2 PC gateways





• [±600A/±40V] power converter

Power Converter Characteristics

Power In $3 \sim 230V/45A$ Power Out+/-600A +/-40VConverter Type4 QuadrantControl typeFGC2 / WorldFipCurrent Accuracy10 ppm(@, 30 mn)

FGC2 / WorldFip 10 ppm@ 30 mn 50 ppm@ 24 h 200 ppm@ 1 year (1 ppm=0.6mA)









- [±500A/±120V] power converter
 - COMET-2P power converters with a 2 MJ crowbar





SubPC#1







- Electrical switches
 - Same switches used in SM18
 - 3 switches integrated per rack (3 racks in total)
- Local control panels (1 per switch)
 - Selection of the test station
 - Protection to avoid change of position with current





- Gateway rack
 - 2 gateways
 - FGC2 gateway for the 600A LHC PCs
 - FGC3 gateway for the COMET PCs
 - Functions:
 - Remote control

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- Gateway rack
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 - FGC2 gateway for the 600A LHC PCs
 - FGC3 gateway for the COMET PCs
 - Functions:
 - Remote control
 - PMB in case of event

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2018	Jun 27	QPS	51_ext		20190625-1	21043.140_RPHHB.163.STATION.3					CLASS_ID	_
2017	Jun 26	PVSS	52_self		20190625-1	20911.100_RPTJ.SM18.RM.F					DATA_STATUS	
2016	Jun 25		52_ext		20190625-1	20752.980_RPHHB.163.STATION.3	- 11				EVENT_GROUP	
2015	Jun 24		53_self		20190625-1	20529.400_RPHHB.163.STATION.3					IEARTH	
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2013	Jun 22		59_self		20190625-1	15750.620_RPHHB.163.STATION.3					LB	
2012	Jun 21		59_ext		20190625-1	15423.080_RPHHB.163.STATION.3					I_DIFF_MA	
2011	Jun 20 -		61_self		20190625-1	15134.260_RPHHB.163.STATION.3					I_EARTH_PONT	
2010	Jun 19		61_ext		20190625-1	15053.800_RPMBA7.BAY5.1_2					I_ERR_MA	
2009	Jun 18		62_self		20190625-1	14349.180_RPHHB.163.STATION.3					I_MEAS	
2008	Jun 17		62_ext		20190625-1	14021.600_RPHHB.163.STATION.3					L_REF	
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	Jun 15		63_ext		20190625-1	13719.240_RPHHB.163.STATION.3					PROPERTY	
	Jun 14		91_self		20190625-1	13657.460_RPTAA.SM18.RM.A					RT_REF	
	Jun 13		91_ext		20190625-1	13429.300_RPMC.311.TRANSTECHNI	(2				STATE_OP	
	Jun 12		92_self		20190625-1	13104.280_RPMC.311.TRANSTECHNI	(2)				STATE_PC	
	Jun 11		92_ext		20190625-1	12915.080_RPTCA.SM18.RM.G					STATE_PLL	
	Jun 10		93_self		20190625-1	12538.720_RPHHB.163.STATION.3					STATE_VS	
	Jun 09		93_ext		20190625-1	11711.160_RPTCA.SM18.RM.G					ST_DCCT_A	
	Jun 08		94_self		20190625-1	11652.920_RPTDA.SM18.RM.B					ST_DCCT_B	
	Jun 07		94_ext		20190625-1	11652.860_RPTDA.SM18.RM.E					ST_FAULTS	
	Jun 06		TEST		20190625-1	11313.060_RPTDD.SM18.RM2.D					ST_LATCHED	
	Jun 05				20190625-1	11257.860_RPHHB.163.STATION.3					ST_MEAS_A	
	Jun 04				20190625-1	11053.460_RPHHB.163.STATION.3					ST_MEAS_B	
	Jun 03				20190625-1	11043.840_RPTCA.SM18.RM.G					ST_UNLATCHED	
	Jun 02				20190625-1	10503.500_RPTCA.SM18.RM.G					ST_WARNINGS	
	Jun 01				20190625-1	05426.780_RPTDD.SM18.RM2.D					SYMBOL	
	May 31				20190625-1	04826.060_RPTCA.SM18.RM.G					T_DOCT_A	
	May 30				20190625-1	04802.000_RPTDA.SM18.RM.C					T_DOCT_B	
	May 29				20190625-1	04055.800_RPMC.311.TRANSTECHNI					T_FGC_IN	
	May 20				20190625-1	03633.620_RPMC.311.1RANSTECHNI	~				ILLEAD NEO	
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							E.	Coulot –	H. Thie	esen, C	ERN TE	-EPC-MPC





- Gateway rack
 - 2 gateways
 - FGC2 gateway for the 600A LHC PCs
 - FGC3 gateway for the COMET PCs
 - Functions:
 - Remote control
 - PMB in case of event



Y Log Undock all Insert all



¹FGC 51 self pmd 20190625-120911.100 RPTJ.5M18.RM.F

Default Scale

Screensho

Scale

Mair

🕂 😥 👘 Menu





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016 Jun 25	52_sti	20190625-1	20752.980 RPHHB.163.STATION.3		Relative Time		Send CSV by Email E	xport To XMG	Export to CSV	Screen Capture	
)15 Jun 24	53_self	20190625-1	120529.400_RPHHB.163.STATION.3								_
014 Jun 23	53_ext	20190625-1	120000.380_RPHHB.163.STATION.3		TIME	RPTJ.SM18.RM.F:ACTION	RPTJ.SM18.RM.F:PROPERT	TY RPTJ.SM18.R	M.F:SYMBOL	<u> </u>	<u> </u>
)13 Jun 22	59_self	20190625-1	115750.620_RPHHB.163.STATION.3		2019/06/25 11:32:34.581999	SET_BIT	STATUS.WARNINGS	REG_ERROR			
)12 Jun 21	59_ext	20190625-1	115423.080_RPHHB.163.STATION.3		2019/06/25 11:32:34.782000	CLR_BIT	STATUS.WARNINGS	REG_ERROR			
10 Jun 19	61_set	20190625-1	115134.200_RPMB_103.STATION.3		2019/06/25 12:06:33.052999	NET.000	PC	SB			
009 Jun 18	62 self	20190625-1	14349.180 RPHHB.163.STATION.3		2019/06/25 12:06:33.057000	SET	STATE.PC	TO_STANDBY			
008 Jun 17	62_ext	20190625-1	114021.600_RPHHB.163.STATION.3		2019/06/25 12:06:33.062000	CLR_BIT	DIG.COMMANDS	AF_RUN			
007 Jun 16	63_self	20190625-1	113748.380_RPMC.311.TRANSTECHNIK.2		2019/06/25 12:08:11.381999	SET_BIT	STATUS.WARNINGS	REG_ERROR			
Jun 15	63_ext	20190625-1	113719.240_RPHHB.163.STATION.3		2019/06/25 12:08:11.461999	CLR BIT	STATUS.WARNINGS	REG ERROR			
Jun 14	91_self	20190625-1	113657.460_RPTAA.SM18.RM.A		2019/06/25 12:09:11.001999	SET_BIT	STATUS.WARNINGS	REG_ERROR			
Jun 13	91_ext	20190625-1	113429.300_RPMC.311.TRANSTECHNIK.2		2019/06/25 12:09:11.081999	SET_BIT	STATUS.FAULTS	REG_ERROR			
Jun 12	92_sell	20190625-1	112915.080 RPTCA SM18 RM G	1	2019/06/25 12:09:11.081999	CLR_BIT	STATUS.WARNINGS	REG_ERROR			
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Jun 09	93_ext	20190625-1	111711.160_RPTCA.SM18.RM.G		2019/06/25 12:09:11.086999	SET	VS.STATE	STOPPING			12:09:12
Jun 08	94_self	20190625-1	111652.920_RPTDA.SM18.RM.B		2019/06/25 12:09:11.086999	CLR_BIT	DIG.STATUS	VS_READY			
Jun 07	94_ext	20190625-1	111652.860_RPTDA.SM18.RM.E		2019/06/25 12:09:11.086999	SET_BIT	DIG.STATUS	PWR_FAILURE			/25
Jun 06	TEST	20190625-1	111313.060_RPTDD.SM18.RM2.D		2019/06/25 12:09:11.086999	CLR_BIT	DIG.STATUS	VS_RUN			
Jun 05		20190625-1	111257.860_RPHHB.163.STATION.3		2019/06/25 12:09:11.086999	SET_BIT	STATUS.ST_UNLATCHED	PWR_FAILURE			
Jun 03		20190625-1	111043.840 BPTCA SM18.BM.G		2019/06/25 12:09:11.086999	SET_BIT	STATUS.ST_UNLATCHED	POST_MORTEN	A		
Jun 02		20190625-1	110503.500_RPTCA.SM18.RM.G		2019/06/25 12:09:11.086999	CLR_BIT	DIG.COMMANDS	VS_RUN			
Jun 01		20190625-1	105426.780_RPTDD.SM18.RM2.D		2019/06/25 12:09:11.086999	SET_BIT	DIG.COMMANDS	FGC_OK			
May 31		20190625-1	104826.060_RPTCA.SM18.RM.G		2019/06/25 12:09:11.092000	SET_BIT	LOG.PM.TRIG	PM_SELF_TRIC	a 👘		
May 30		20190625-1	104802.000_RPTDA.SM18.RM.C		2019/06/25 12:09:11.102000	SET_BIT	STATUS.ST_UNLATCHED	LOW_CURREN	T		
May 29		20190625-1	104055.800_RPMC.311.TRANSTECHNIK.2		2019/06/25 12:09:11.121999	CLR_BIT	STATUS.ST_UNLATCHED	LOW_CURREN	T		
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May 26		20190625-1	103218.420 RPMC.311.TRANSTECHNIK.2		2019/06/25 12:09:11.161999	SET_BIT	DCCT.A.STATUS	ZERO_I			
May 25		20190625-1	102725.960_RPTDA.SM18.RM.B	SYSTEM: FGC	2019/06/25 12:09:11.161999	SET_BIT	DCCT.B.STATUS	ZERO_I			A COMPANY OF
May 24		20190625-1	102637.480_RPTDA.SM18.RM.C	SOURCE: RPTJ.SM18.RM.F CLASS: 51 self pmd	2019/06/25 12:09:11.187000	SET	STATE.PC	FLT_OFF			
May 23		20190625-1	102533.800_RPTCA.SM18.RM.G	TIME: 2019-06-25 12:09:11.100	2019/06/25 12:09:11.187000	SET	VS.STATE	OFF			
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FGC 51_self_pmd 20190625-120911 100_PPT1SM18.PM

Default Scale

Screensho

Scale Analysis

🕂 📮 👘 Menu





- Gateway rack
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	 TIMBER for analysis 			<u> </u>	9 H 🙆 🗠 🖬	🖬 🔬 🖉 Cursor Coordinates 🔲 S	hapitolline 🔛 🖓 🖓 🚺 reset	Thenes : Black-on-White	•			
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• Elapsed: 206ms







[±600A/±40V] test station



 Each device has been tested individually in the TE-EPC test station to verify its performances



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- After their installation, the power converters have been tested in short circuit to verify
 - The services (AC distribution (normal and UPS) and water cooling system)
 - The Gateways (Remote control, PMB, TIMBER)
 - The DC cables (partial test between PC and electrical switches)





- Additional tests have been realized with other equipment owners to verify the power converter interfaces
 - EN-SMM for the communication with the control room
 - TE-MSC for the communication with the protection PLC
 - TE-MPE for the QPS







• What have not been tested?







- What have not been tested?
 - DC cables between the electrical switches and the test station





- What have not been tested?
 - The operation of the power converter with the magnet
 - · Setting of the digital current loop
 - Normal behaviors during the different events
 - PC faults
 - Discharge with and W/O energy extraction system, etc...
 - Performance tests





- The tests with magnet have to be done step by step and magnet by magnet
 - w/o current
 - Low current (10%)
 - Intermediate currents (25, 50, 75%)
 - Nominal current (100%)
 - Ultimate current (120%)
 - All the magnets together (multiplet)





- The commissioning tests have to be repeated (partially) for each type of magnets
 - Different inductance
 - Different stored energy





Dipole magnet

Multiplet magnet





- TE-EPC has provided 9 high performance power converters fully compliant with the specification of the SuperFRS magnet test facility at CERN
- Standard power converters have been chose to reduce the cost of the project and for operational raisons
- All power converters have been tested individually and in short circuit to verify their performances and the infrastructure (EN/EL, EN/CV, Control, etc...)
- Interface tests have been done with the other equipment owners to valid the different interfaces (EN/SMM, TE/MSC, TE/MPE, etc...)

TE-EPC is ready for the commissioning of the test facility with SuperFRS magnets





Thank you for your attention





• Main parameters of the SuperFRS magnets

		L	I_inj	I_nom	I_ult	Rise 7	Time	
Magnet type	EE system*	[H]	[A]	[A]	[A]	[S]	
D2	1 kV	17.362	23	232	278.4]	100	
D3	1 kV	15.380	23	232	278.4		100	
D4	1 kV	32.344	22	227	272.4		100	
Q3	1 kV	25.360	29	292	350.4		100	
Q4	1 kV	38.040	29	292	350.4		100	
Q5	1 kV	25.360	29	292	350.4		100	
Q6	1 kV	38.040	29	292	350.4		100	
Q7	1 kV	21.547	30	300	360		100	
Q8	1 kV	32.320	30	300	360		100	
S	non	1.776	17	171	205.2		100	
0	non	0.031	30	300	360		100	
D	non	0.044	30	300	360		100	
		~ 40 H			< 400 A	L	ow L.di/d	۲t

The SuperFRS magnets are characterized by:

- Low current
- High inductance (high energy stored)
- High rise time (low inductive voltage)

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- 9 power converters are needed to test SuperFRS cryostats (full multiplet):
 - 3 for the main magnets (dipoles or quadrupoles)
 - 6 for the correctors

