

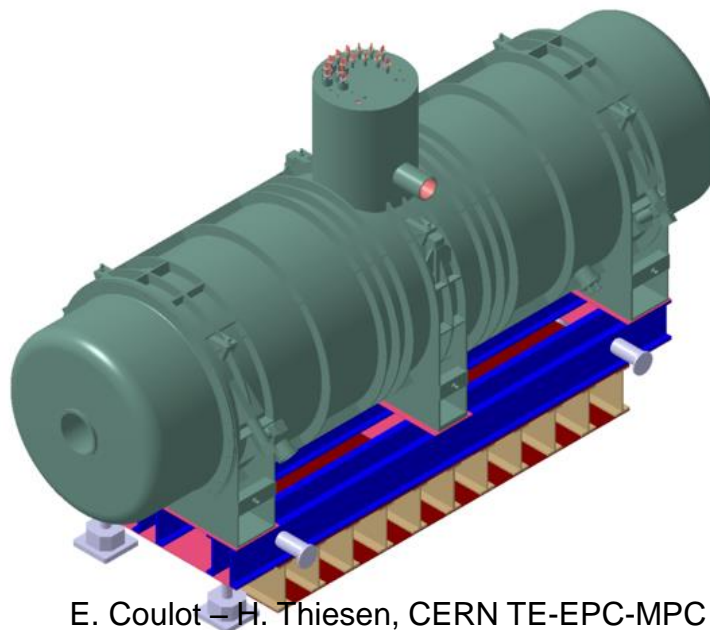
Power Converters for Super-FRS Magnet Test Facility at CERN

- 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	dipole	2 t/50t	0.5 MJ	1.6 T	~ 230 A
23	multiplet 1	45t/60t	1.5 MJ	2.5 T	~ 300 A
8	multiplet 2	35t/60t	1 MJ	2.5 T	~ 230 A



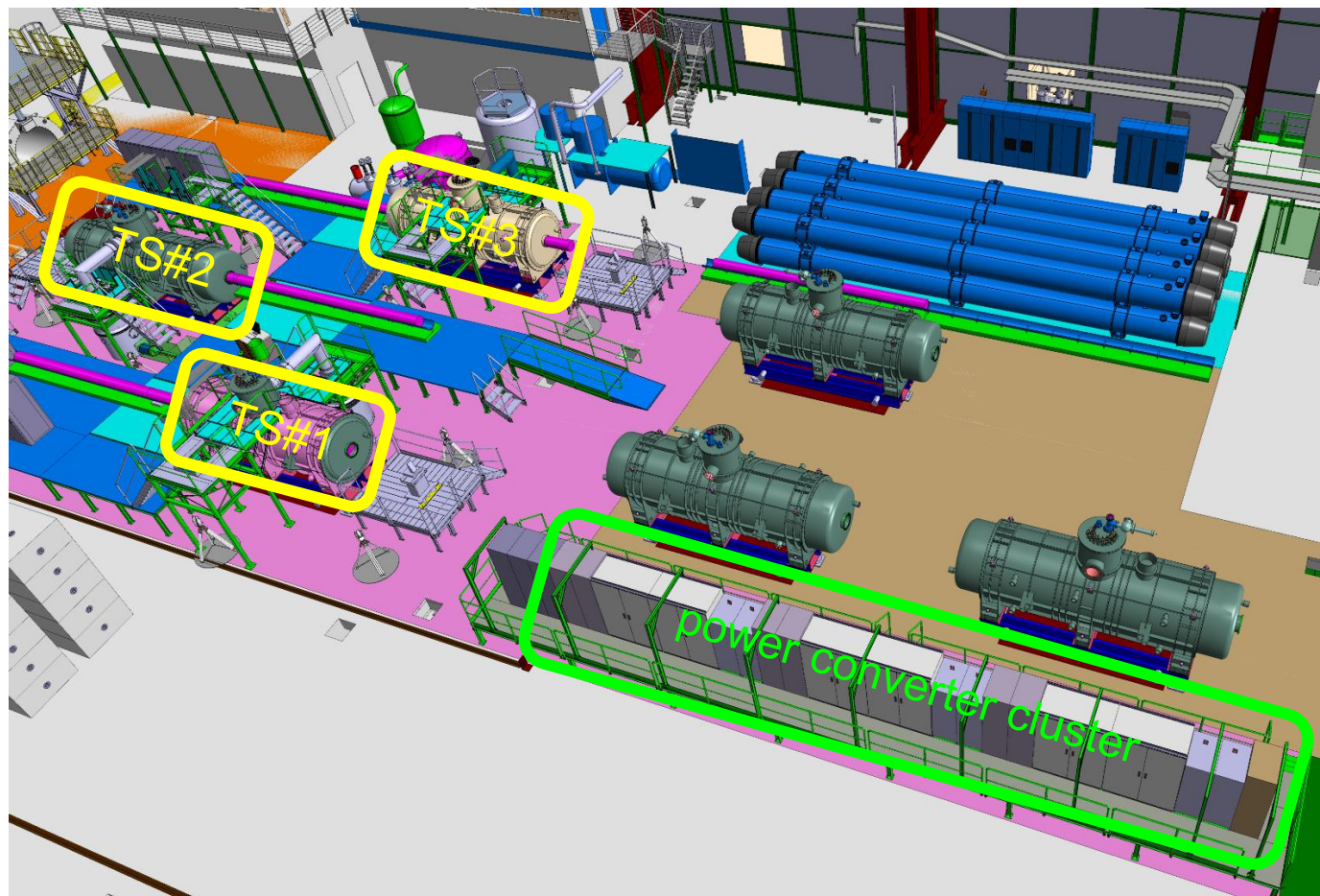
- 2 types of cryostats:
 - Dipole cryostats:
 - Only one dipole magnet inside the cryostats (no correctors)
 - Multiplets cryostats:
 - Quadrupole and corrector magnets are integrated inside the multiplets
 - Different multiplets configurations with a maximum of 9 magnets:
 - 3 quadrupoles
 - 6 correctors (S, O and D magnets)



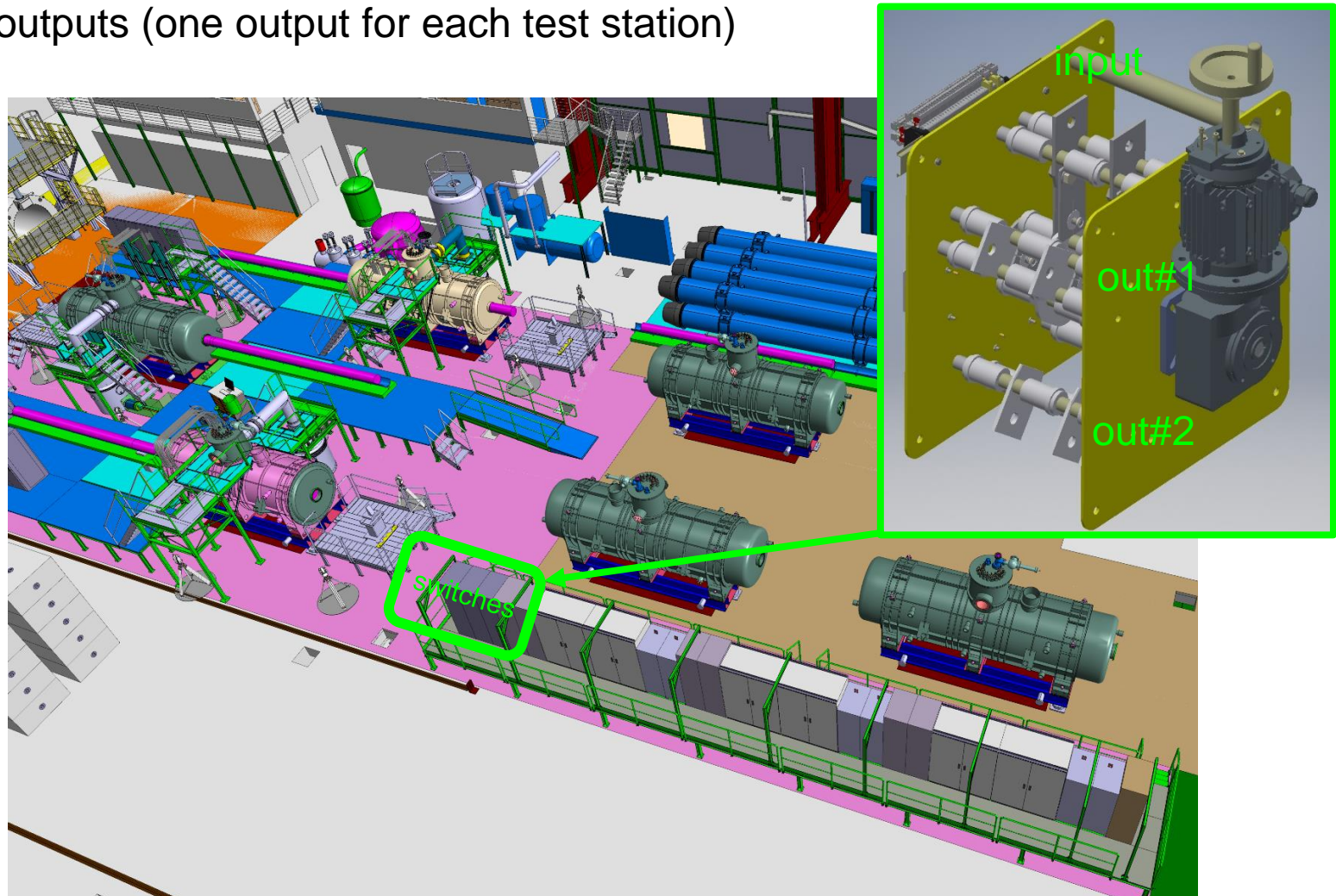
Example of multiplet (FHF1YMQ11)

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)



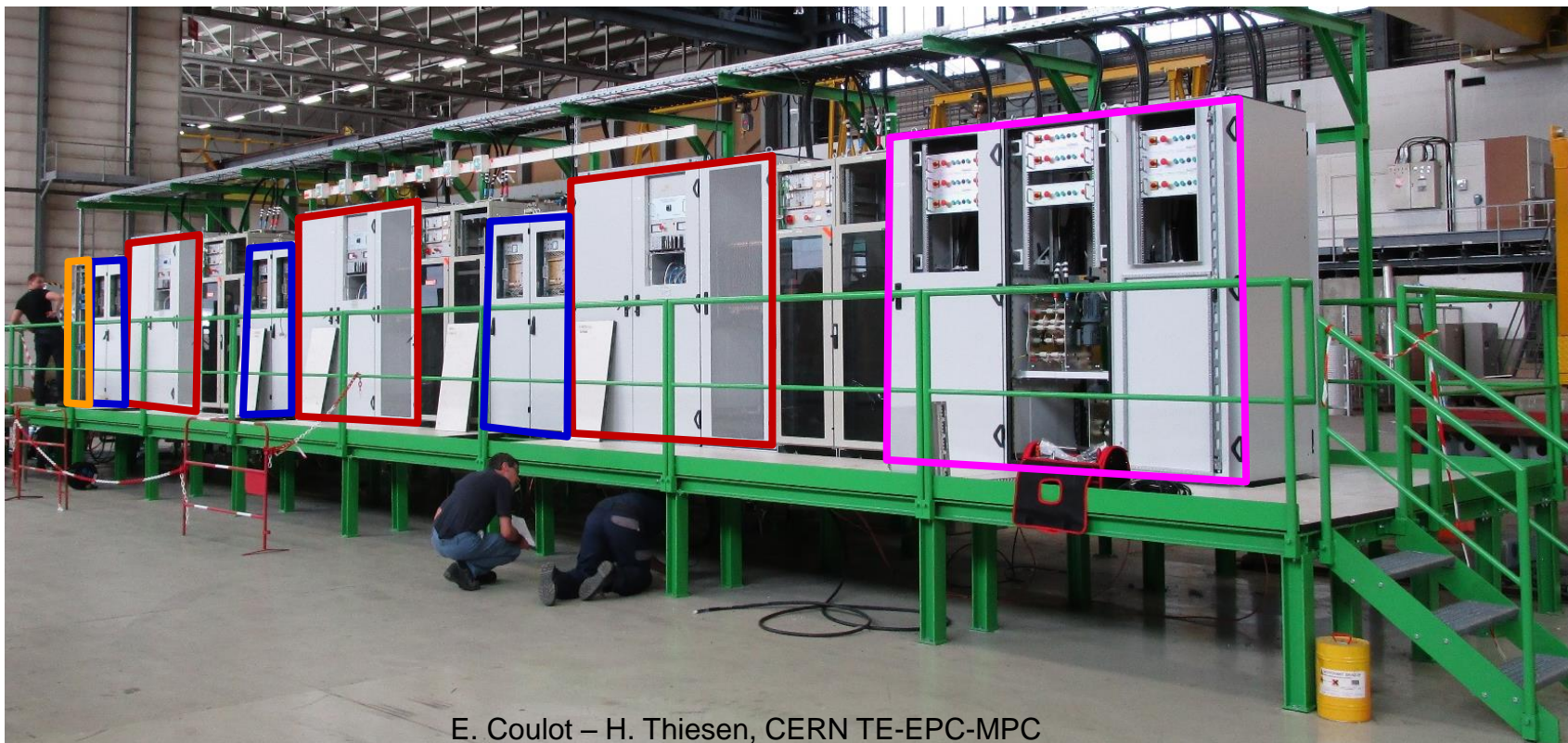
- The selection of the test stations is done by electrical switches
 - 1 input (connected to the power converter)
 - 3 outputs (one output for each test station)



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

Magnet type	EE system	L [H]	r_cable* [Ohm]	Tau [s]	I_inj [A]	I_nom [A]	I_ult [A]	E_nom [MJ]	E_ult [MJ]	Rise Time [s]	U_boost [V]	U_max_ult [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]
O	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]

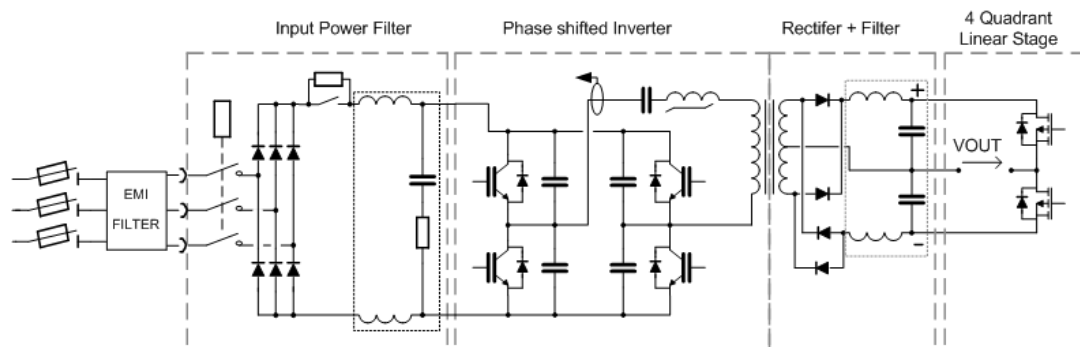
- To limit the cost of the project TE-EPC has chosen standard power converters
 - 6 x $[\pm 600\text{A}/\pm 40\text{V}]$ LHC power converters for the corrector magnets
 - 3 x $[\pm 500\text{A}/\pm 120\text{V}]$ COMET-2P power converters for the main magnets (D & Q)
- TE-EPC is also responsible for
 -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



- [$\pm 600A/\pm 40V$] power converter

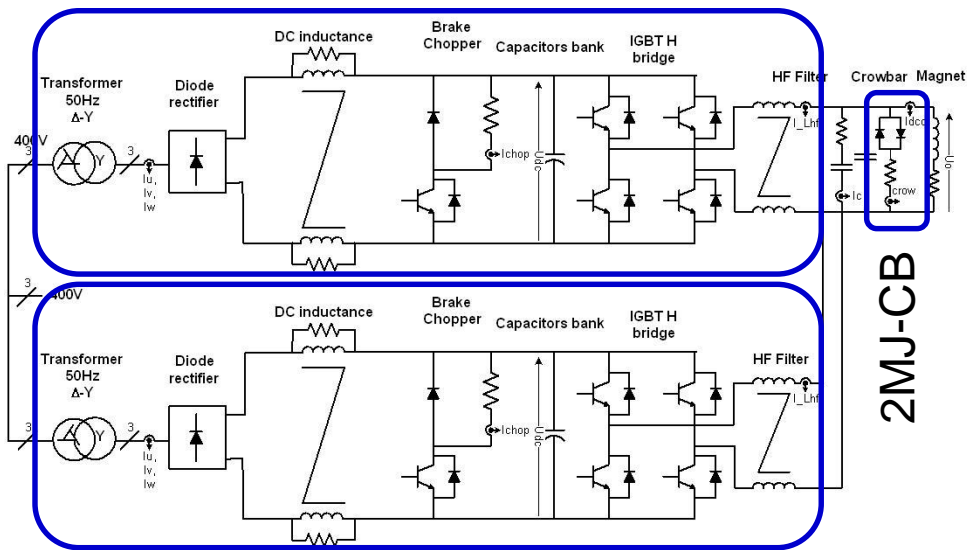
Power Converter Characteristics

Power In	$3 \sim 230V/45A$
Power Out	$\pm 600A \pm 40V$
Converter Type	<i>4 Quadrant</i>
Control type	<i>FGC2 / WorldFip</i>
Current Accuracy	$10 \text{ ppm@ } 30 \text{ mn}$ $50 \text{ ppm@ } 24 \text{ h}$ $200 \text{ ppm@ } 1 \text{ year}$ $(1 \text{ ppm}=0.6mA)$



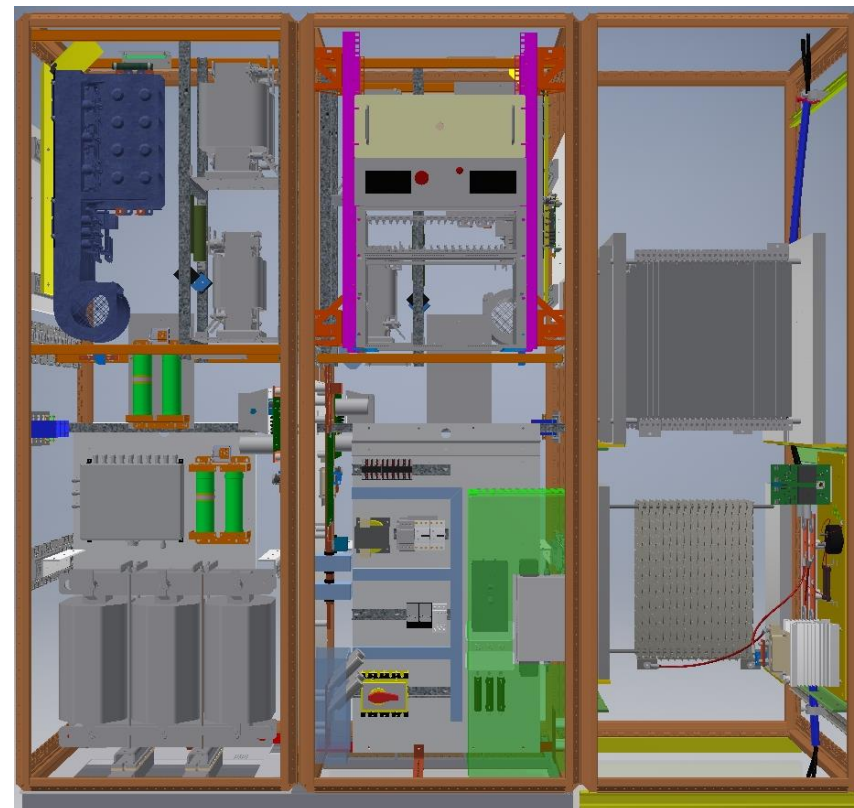
- [$\pm 500\text{A}/\pm 120\text{V}$] power converter
 - COMET-2P power converters with a 2 MJ crowbar

SubPC#1



SubPC#2

2MJ-CB

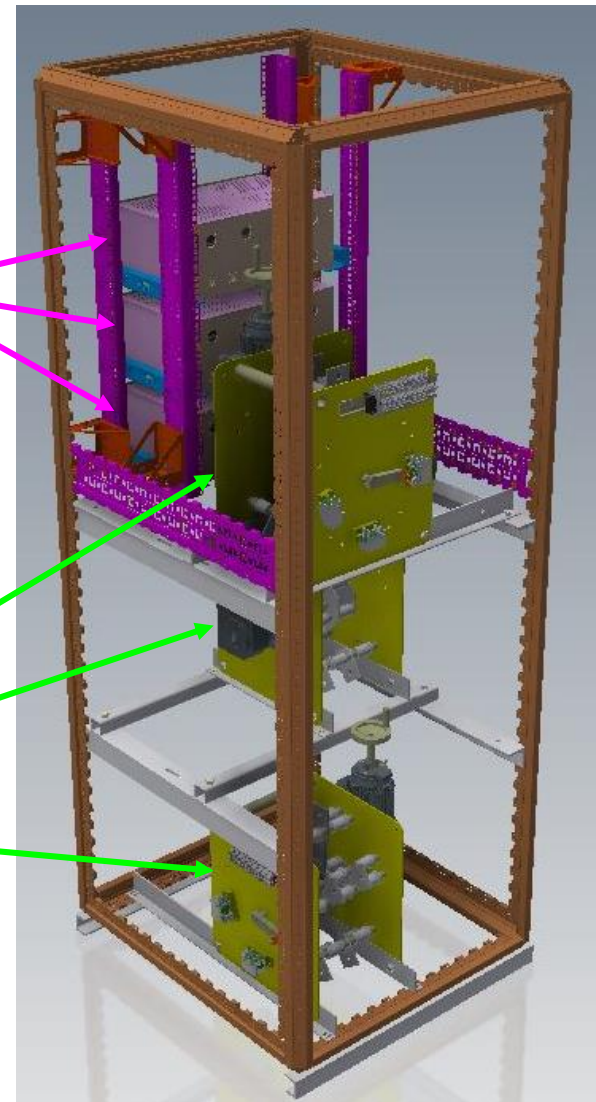
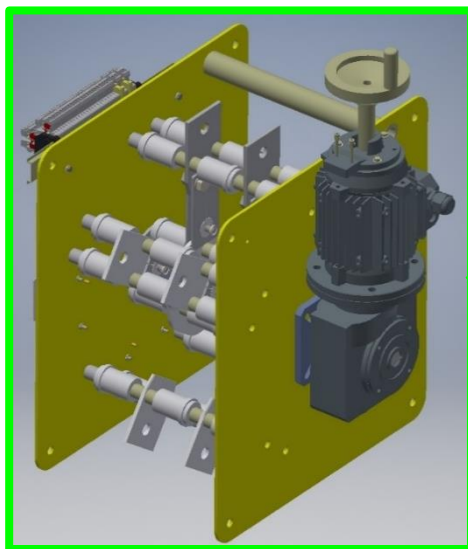


SubPC#1

SubPC#2

2MJ-CB

- 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

FGCRun+ - RBAC token expires Fri Jun 28 19:12:05 2019

File Connect Disconnect Gateway FGC Database List Analysis RBAC Help

Connect devices: .180.

PL.OP.VS.PC I_REF I_MEAS V_REF V_MEAS 11 / 11 / 98 Username: hthiesen Password: *****

FGC_Ether gateway				CFC-180-RETH1
FGC_WorldFIP gateway				CFC-180-RFIP1
LK.NL.PA.FO	0.00	-0.01	0.00	0.00
LK.NL.PA.FO	0.00	0.01	0.00	0.00
LK.NL.PA.FO	0.00	-0.01	0.00	-0.00
LK.NL.FO.FO	0.00	0.00	0.00	0.12
LK.NL.FO.FO	0.00	-0.00	0.00	0.11
LK.NL.FO.FO	0.00	0.00	0.00	0.11
LK.NL.FO.FO	0.00	-0.00	0.00	0.11
LK.NL.FO.FO	0.00	0.01	0.00	0.11
LK.NL.FO.FO	0.00	-0.00	0.00	0.11
				RPAEG.180.RM.10
				RPAEG.180.RM.20
				RPAEG.180.RM.30
				RPMC.180.RC.10
				RPMC.180.RC.11
				RPMC.180.RC.20
				RPMC.180.RC.21
				RPMC.180.RC.30
				RPMC.180.RC.31

Send



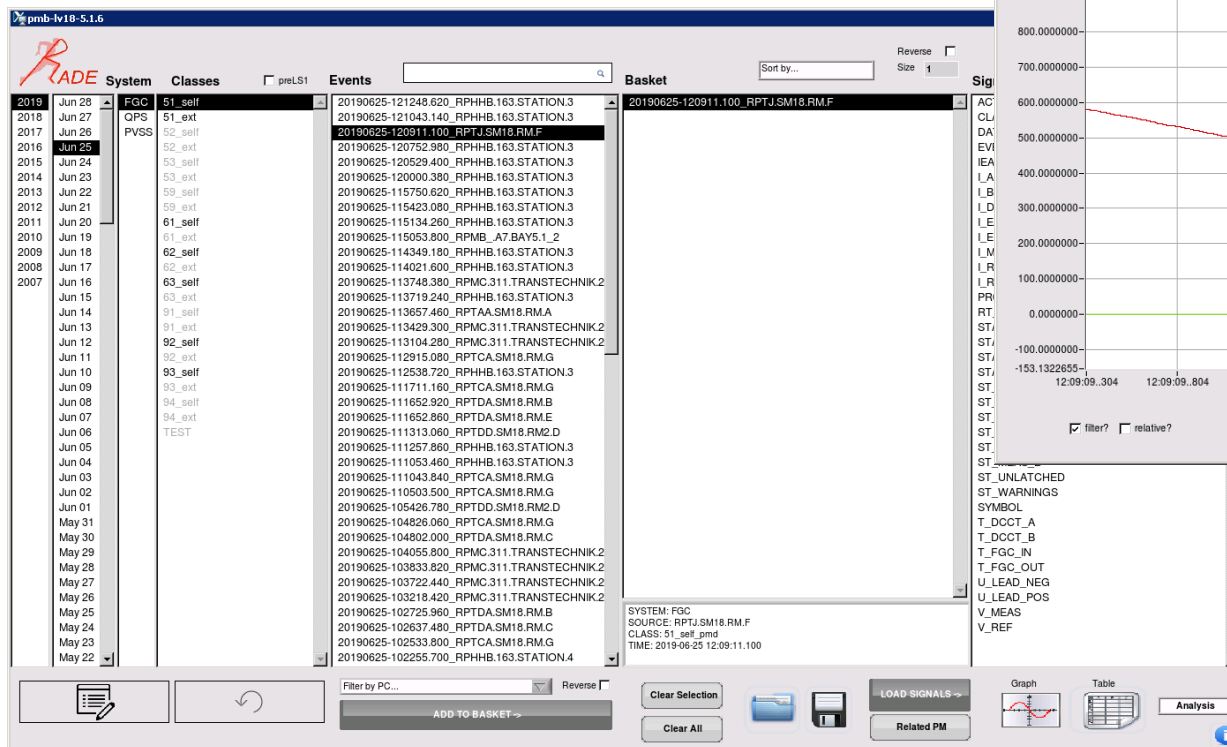
- Gateway rack
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 - FGC2 gateway for the 600A LHC PCs
 - FGC3 gateway for the COMET PCs
 - Functions:
 - Remote control
 - PMB in case of event

The screenshot displays the RADE System interface with the following sections:

- System:** RADE System
- Classes:** FGC, 51_self, QPS, PVSS
- Events:** A list of events with columns for year, month, day, and event ID. The selected event is 20190625-120911.100_RPTJ.SM18.RMF.
- Basket:** 20190625-120911.100_RPTJ.SM18.RMF
- Signals:** A list of signals including ACTION, CLASS_ID, DATA_STATUS, EVENT_GROUP, IEARTH, LA, LB, L_DIFF_MA, LEARTH_PCNT, LERR_MA, L_MEAS, L_REF, L_REF_RST, PROPERTY, RT_REF, STATE_OP, STATE_PC, STATE_PLL, STATE_VS, ST_DCCT_A, ST_DCCT_B, ST_FAULTS, ST_LATCHED, ST_MEAS_A, ST_MEAS_B, ST_UNLATCHED, ST_WARNINGS, SYMBOL, T_DCCT_A, T_DCCT_B, T_FGC_IN, T_FGC_OUT, U_LEAD_NEG, U_LEAD_POS, V_MEAS, V_REF.
- Footer:** Filter by PC..., Reverse, Clear Selection, ADD TO BASKET, Clear All, LOAD SIGNALS, Related PM, Graph, Table, Analysis.



- Gateway rack
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 - Functions:
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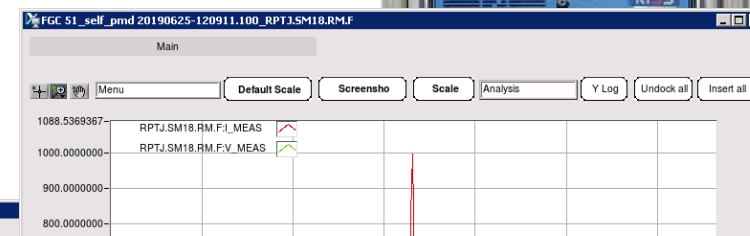


RADE System

Classes: preLS1

Events:

Year	Month	Day	Class	Event
2019	Jun	28	FGC	51_self
2018	Jun	27	QPS	62_ext
2017	Jun	26	PVSS	62_ext
2016	Jun	25		62_ext
2015	Jun	24		63_self
2014	Jun	23		63_ext
2013	Jun	22		59_self
2012	Jun	21		59_ext
2011	Jun	20		61_self
2010	Jun	19		61_ext
2009	Jun	18		62_self
2009	Jun	17		62_ext
2008	Jun	17		63_self
2007	Jun	16		63_ext
	Jun	15		91_ext
	Jun	14		91_ext
	Jun	13		91_ext
	Jun	12		92_self
	Jun	12		92_ext
	Jun	11		92_ext
	Jun	10		93_self
	Jun	09		93_ext
	Jun	08		94_self
	Jun	07		94_ext
	Jun	06		TEST
	Jun	06		TEST
	Jun	05		TEST
	Jun	04		TEST
	Jun	03		TEST
	Jun	02		TEST
	Jun	01		TEST
	May	31		TEST
	May	30		TEST
	May	29		TEST
	May	28		TEST
	May	27		TEST
	May	26		TEST
	May	25		TEST
	May	24		TEST
	May	23		TEST
	May	22		TEST

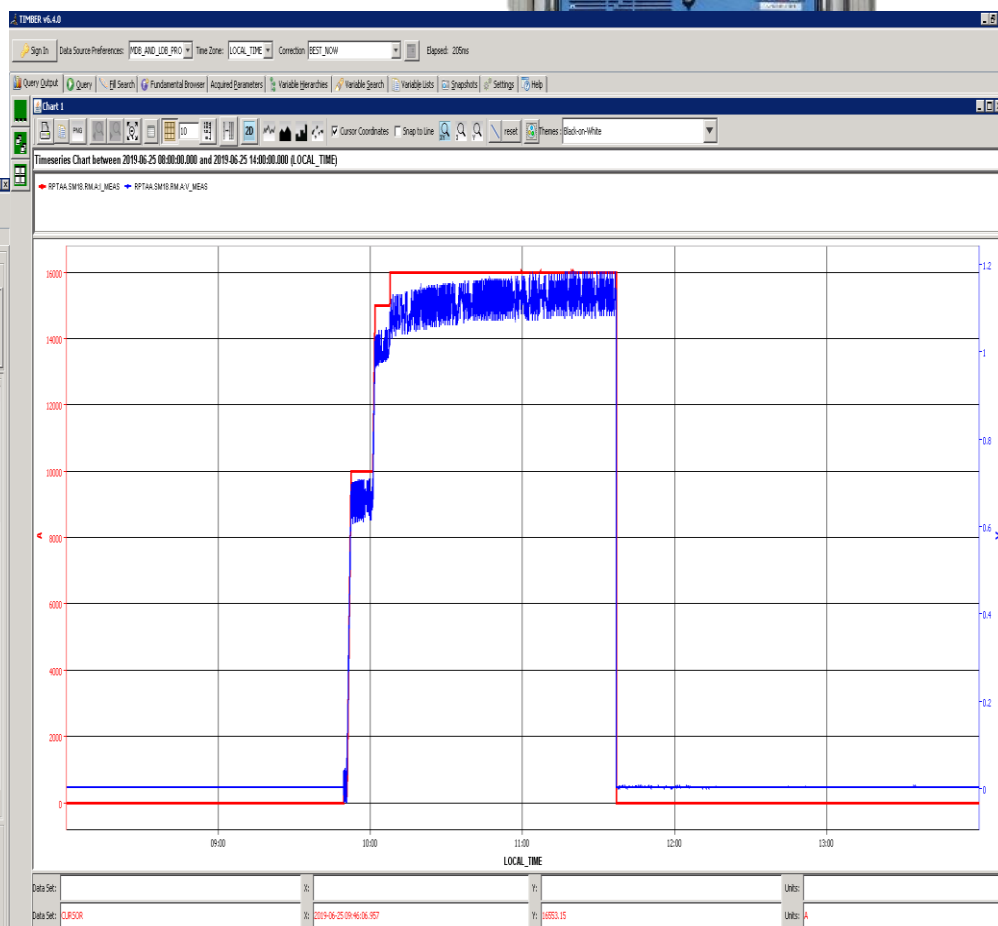
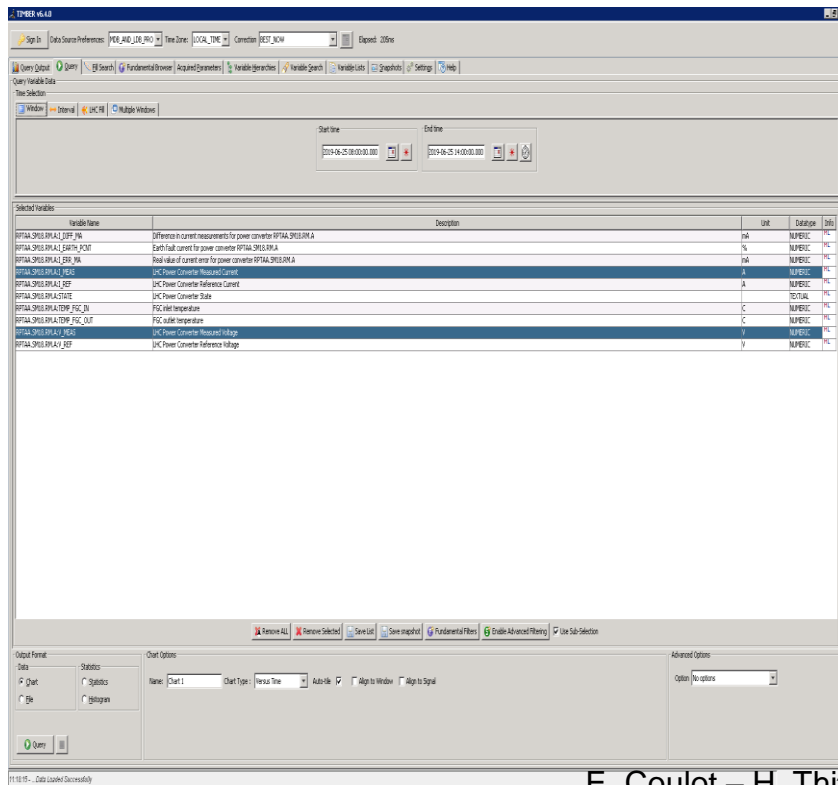


FGC 51_self_pmd 20190625-120911.100_RPTJ.SM18.RMF

Relative Time Send CSV by Email Export To XMG Export to CSV Screen Capture

TIME	RPTJ.SM18.RM.F:ACTION	RPTJ.SM18.RM.F:PROPERTY	RPTJ.SM18.RM.F:SYMBOL
2019/06/25 11:32:34.581999	SET_BIT	STATUS.WARNINGS	REG_ERROR
2019/06/25 11:32:34.782000	CLR_BIT	STATUS.WARNINGS	REG_ERROR
2019/06/25 12:06:33.052999	NET.000	PC	SB
2019/06/25 12:06:33.057000	SET	STATE.PC	TO_STANDBY
2019/06/25 12:06:33.062000	CLR_BIT	DIG.COMMANDS	AF_RUN
2019/06/25 12:08:11.381999	SET_BIT	STATUS.WARNINGS	REG_ERROR
2019/06/25 12:08:11.461999	CLR_BIT	STATUS.WARNINGS	REG_ERROR
2019/06/25 12:09:11.001999	SET_BIT	STATUS.WARNINGS	REG_ERROR
2019/06/25 12:09:11.081999	SET_BIT	STATUS.FAULTS	REG_ERROR
2019/06/25 12:09:11.081999	CLR_BIT	STATUS.WARNINGS	REG_ERROR
2019/06/25 12:09:11.086999	SET	STATE.PC	FLT_STOPPING
2019/06/25 12:09:11.086999	SET	VS.STATE	STOPPING
2019/06/25 12:09:11.086999	CLR_BIT	DIG.STATUS	VS_READY
2019/06/25 12:09:11.086999	SET_BIT	DIG.STATUS	PWR_FAILURE
2019/06/25 12:09:11.086999	CLR_BIT	DIG.STATUS	VS_RUN
2019/06/25 12:09:11.086999	SET_BIT	STATUS.ST_UNLATCHED	PWR_FAILURE
2019/06/25 12:09:11.086999	SET_BIT	STATUS.ST_UNLATCHED	POST_MORTEM
2019/06/25 12:09:11.086999	CLR_BIT	DIG.COMMANDS	VS_RUN
2019/06/25 12:09:11.086999	SET_BIT	DIG.COMMANDS	FGC_OK
2019/06/25 12:09:11.092000	SET_BIT	LOG.PM.TRIG	PM_SELF_TRIG
2019/06/25 12:09:11.102000	SET_BIT	STATUS.ST_UNLATCHED	LOW_CURRENT
2019/06/25 12:09:11.121999	CLR_BIT	STATUS.ST_UNLATCHED	LOW_CURRENT
2019/06/25 12:09:11.142000	SET_BIT	STATUS.ST_UNLATCHED	LOW_CURRENT
2019/06/25 12:09:11.161999	SET_BIT	DCCT.A.STATUS	ZERO_I
2019/06/25 12:09:11.161999	SET_BIT	DCCT.B.STATUS	ZERO_I
2019/06/25 12:09:11.187000	SET	STATE.PC	FLT_OFF
2019/06/25 12:09:11.187000	SET	VS.STATE	OFF
2019/06/25 12:09:11.187000	CLR_BIT	DIG.STATUS	VS_POWER_ON
2019/06/25 12:09:11.187000	CLR_BIT	STATUS.ST_UNLATCHED	VS_POWER_ON
2019/06/25 12:09:31.001999	CLR_BIT	LOG.PM.TRIG	PM_SELF_TRIG

- 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
 - **TIMBER** for analysis



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

[±600A/±40V] test station



- 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)



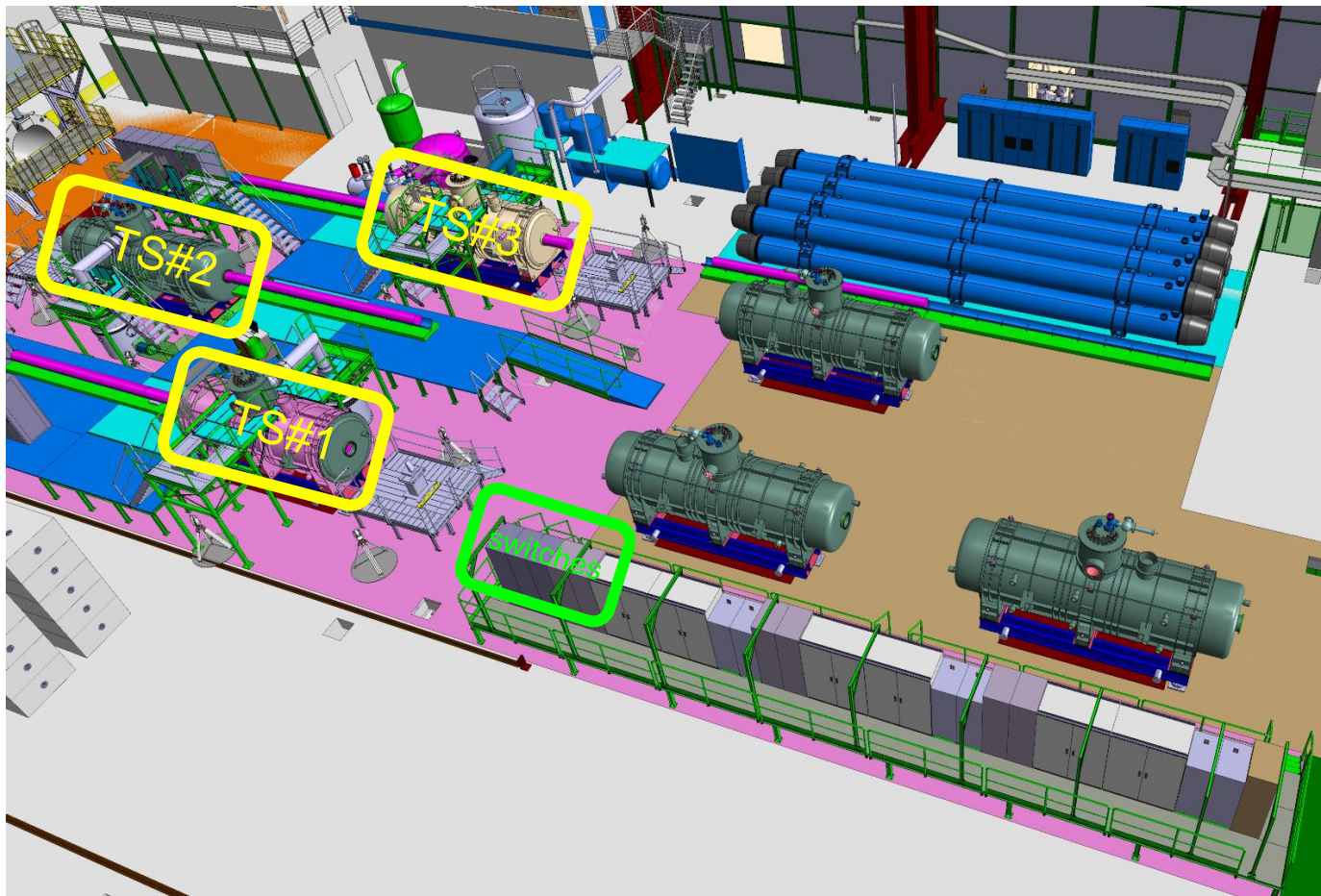
- Additional tests have been realized with other equipment owners to verify the power converter interfaces
 - EN-SMM for the communication with the control room
 - TE-MSD for the communication with the protection PLC
 - TE-MPE for the QPS



- What have not been tested?



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



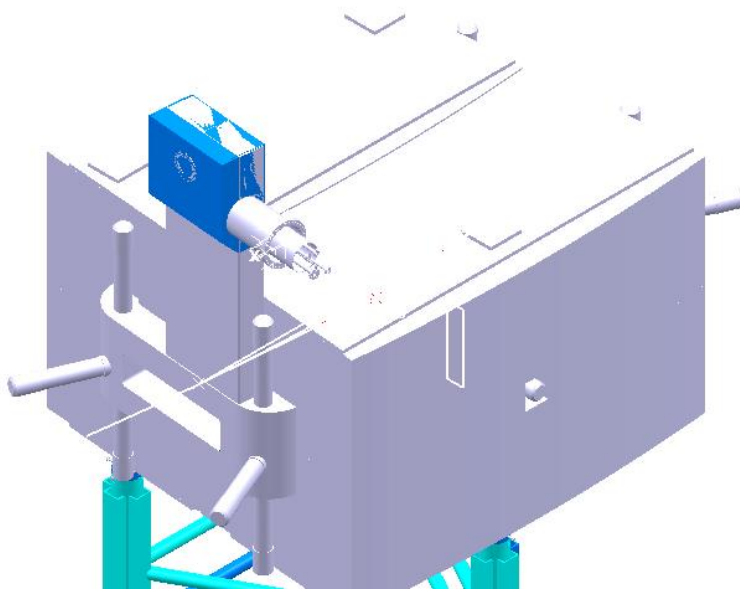
- What have not been tested?
 - The operation of the power converter with the magnet
 - Setting of the digital current loop
 - Normal behaviors during the different events
 - PC faults
 - Discharge with and W/O energy extraction system, etc...
 - Performance tests



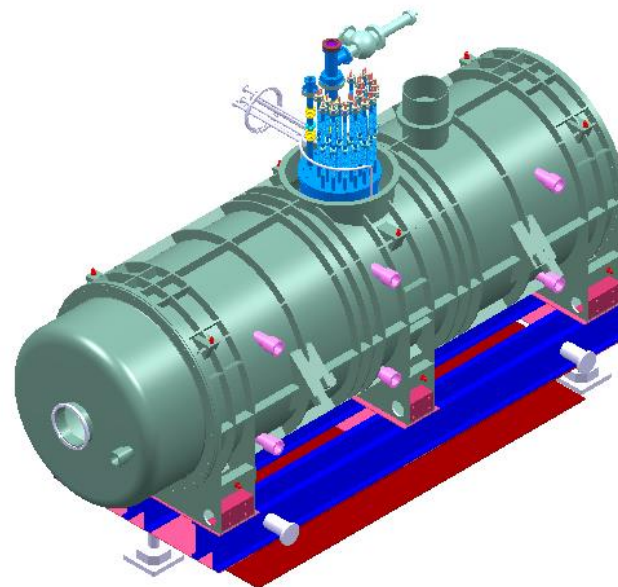
- The tests with magnet have to be done step by step and magnet by magnet
 - w/o current
 - Low current (10%)
 - Intermediate currents (25, 50, 75%)
 - Nominal current (100%)
 - Ultimate current (120%)
 - All the magnets together (multiplet)



- 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 chosen to reduce the cost of the project and for operational reasons
- 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 validate the different interfaces (EN/SMM, TE/MS, 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

Magnet type	EE system*	L [H]	I_inj [A]	I_nom [A]	I_ult [A]	Rise Time [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
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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
O	non	0.031	30	300	360	100
D	non	0.044	30	300	360	100

~ 40 H
< 400 A
Low L.di/dt

The SuperFRS magnets are characterized by:

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

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

