Elettra Sincrotrone Trieste

Elettra
Sincrotrone
Trieste

Power Converters Lab

Elettra 2.0 Corrector, Multipolar and Dipole Power Converters

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Preface

Goal:

minimize, with the magnet designers, the number of types of power supplies for the various typologies of magnets, using the same controller for all kinds.

Benefits:

- Cost reduction, maintenance and spare parts management
- Unification of the control hardware (e.g. Ethernet interface with TCP-IP), interlock signals, and software.

Water Vs Air cooling

Experience at Elettra:

- Water-cooling has caused and still causes a non-negligible source of downtime. Sometimes leaks are fatal to the electronics.
- Air-cooling requires stable air temperature and a constant flow to maximize stability of the power supplies.
- We will place the power converters inside normal racks, heat load to the Service Gallery has to be considered.

One to One

One-to-one correspondence (power supplies – magnets):

- implies large number of power cables to the SR
- Power converters placed in the same positions of the present cabinets allows using the existing cable trays.
- Short cables limit the EMI spread.

Optimization

Magnet-Power Converters optimization:

- 2 types of dipoles use the same type of converter.
- 3 types of quadrupoles and 3 types of sextupoles require only one type of power converter.
- the embedded correctors, fast correctors, skew quadrupoles and ID corr.coils use the same type of power converter.

In total we have just 3 kinds of Power Converters for the entire machine

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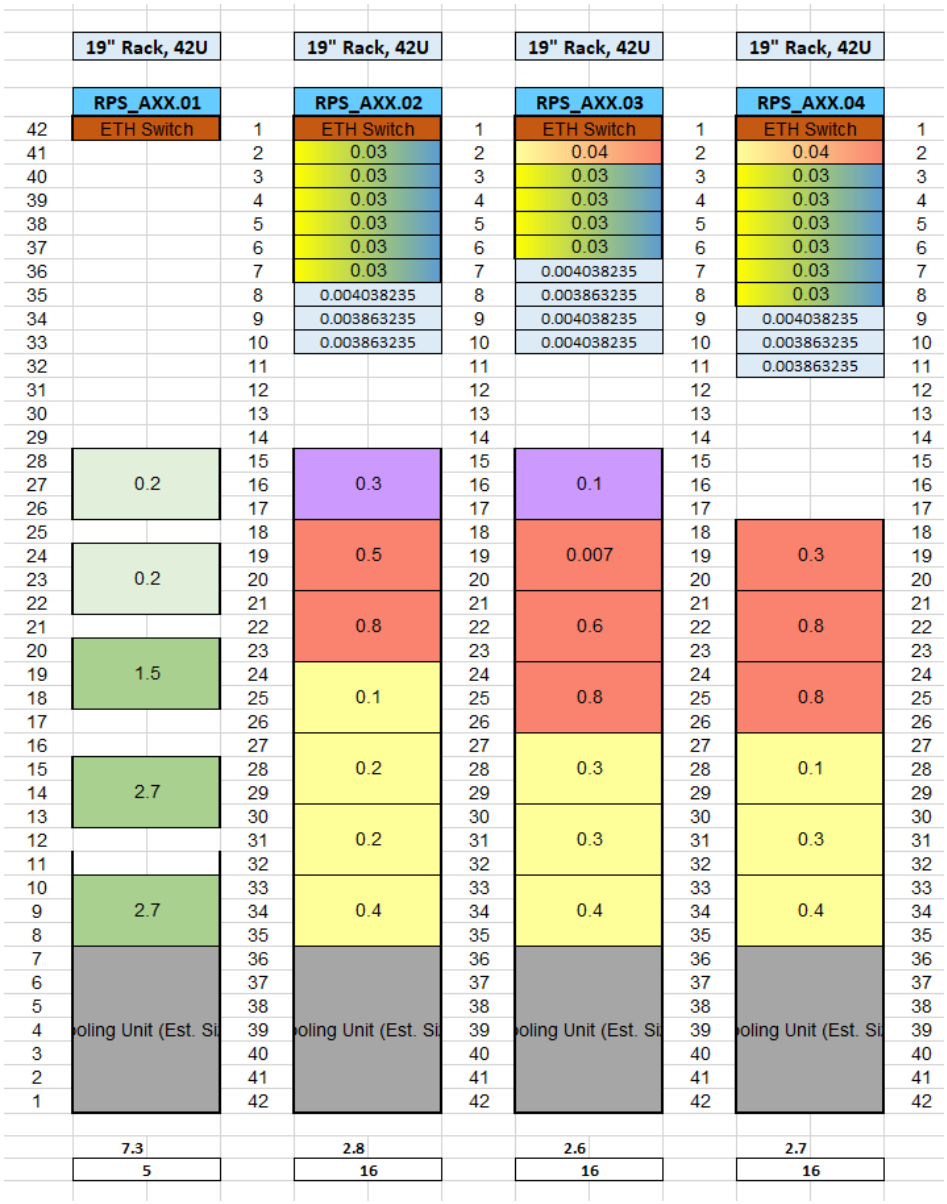
Specifications from Machine Physicists

Magnet Type	Dipole	Sext	Quad	Skew-Quad	Corr	Oct	PSB TrimC	Fast Corr	Unit
PS Mode	Unipolar			Bipolar		Unipolar	Bipolar	Bipolar	
PS Type	PSB	PSQS		PSC		PSOC	PSB_T	PSFC	
Max Iout	**300**	**100**		**25**		**100**	**100**	**5**	A
Max Vout	20	15	15	10	10	10	5	*TBD*	V
Max Pout	6	1.5	1.5	0.2	0.2	1.0	0.5	5*Vout	kW
Op. Range	5 – 95	5 – 95	5 – 95	Full	Full	5 – 95	Full	Full	% Iout
Stability (8h)	30	100	25	50	20	100	100	20	ppm_{pp}/FS
Ripple	30	100	100	100	500	100	100	500	ppm_{pp}/FS
Total PS	72	432		432		48	48	192	**1224**

Island configuration (achromat half cell)



	19" Rack, 42U		19" Rack, 42U		19" Rack, 42U		19" Rack, 42U	
	RPS_AXX.01		RPS_AXX.02		RPS_AXX.03		RPS_AXX.04	
42	ETH Switch	1	ETH Switch	1	ETH Switch	1	ETH Switch	1
41		2	0.03	2	0.04	2	0.04	2
40		3	0.03	3	0.03	3	0.03	3
39		4	0.03	4	0.03	4	0.03	4
38		5	0.03	5	0.03	5	0.03	5
37		6	0.03	6	0.03	6	0.03	6
36		7	0.03	7	0.004038235	7	0.03	7
35		8	0.004038235	8	0.003863235	8	0.03	8
34		9	0.003863235	9	0.004038235	9	0.004038235	9
33		10	0.003863235	10	0.004038235	10	0.003863235	10
32		11		11		11	0.003863235	11
31		12		12		12		12
30		13		13		13		13
29		14		14		14		14
28		15		15		15		15
27	0.2	16	0.3	16	0.1	16		16
26		17		17		17		17
25		18		18		18		18
24		19	0.5	19	0.007	19	0.3	19
23	0.2	20		20		20		20
22		21		21		21		21
21		22	0.8	22	0.6	22	0.8	22
20		23		23		23		23
19	1.5	24		24		24		24
18		25	0.1	25	0.8	25	0.8	25
17		26		26		26		26
16		27		27		27		27
15		28	0.2	28	0.3	28	0.1	28
14	2.7	29		29		29		29
13		30		30		30		30
12		31	0.2	31	0.3	31	0.3	31
11		32		32		32		32
10		33		33		33		33
9	2.7	34	0.4	34	0.4	34	0.4	34
8		35		35		35		35
7		36		36		36		36
6		37		37		37		37
5		38		38		38		38
4	oling Unit (Est. Si	39	oling Unit (Est. Si	39	oling Unit (Est. Si	39	oling Unit (Est. Si	39
3		40		40		40		40
2		41		41		41		41
1		42		42		42		42
	7.3		2.8		2.6		2.7	
	5		16		16		16	

We'll have 24 half cells distributed around the ring (96 racks)

Standardization

Dual AC mains inputs:
Power: 3-phase 400 VAC or 1-phase 230 VAC
Control: 1-phase 230 VAC from UPS to energize the control and regulation part.

In case of mains outage on the power line, the control remains active to monitor the power supply and keeps it connected to the control system.

Standardization

Dipoles:
currents and voltages are compatible with high-performance products on the market. Winner of the CFT was RTI OCEM-CAENels with their NGPS power converter. Expected size is standard 19”, 3U.

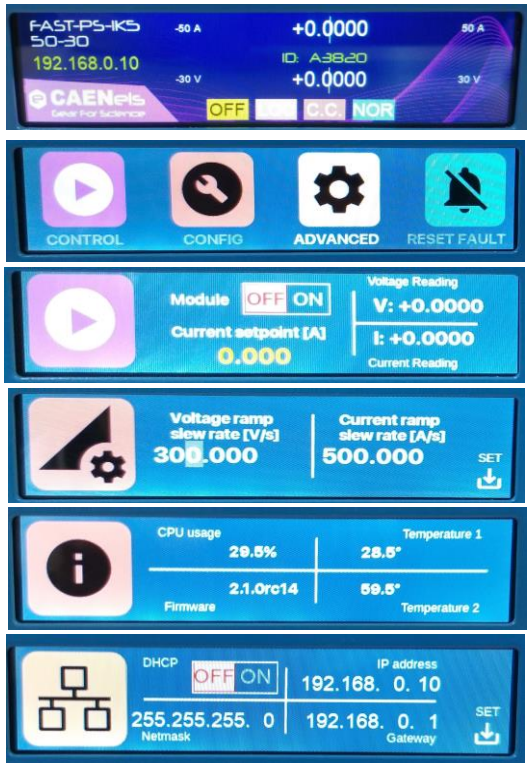
Standardization

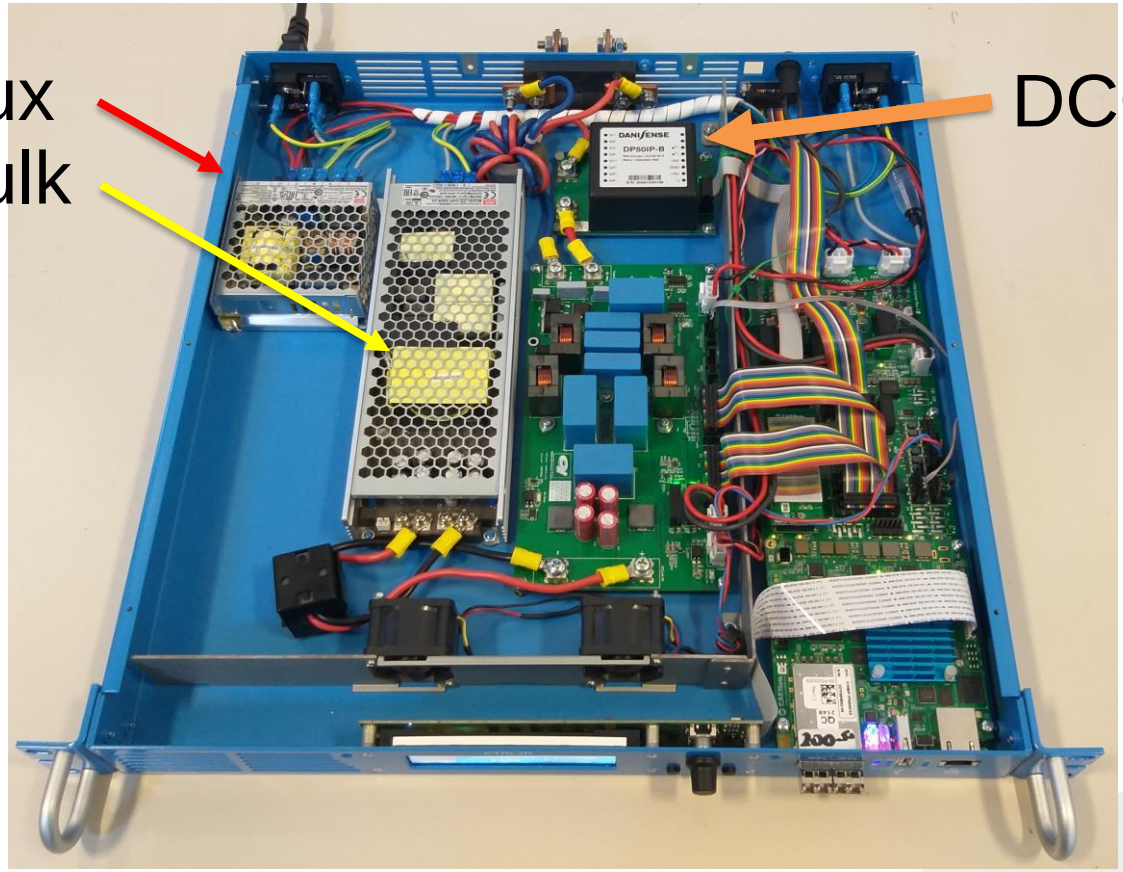
(fast) Correctors, Skew Quadrupoles and ID corr.coils:

this power converter shall be an “in-house” development.
4-Quadrant operation, 25 A max.
Expected size is standard 19”, 1U high

the power part has f_s=100 kHz and 4th order output filter, plus 2 SFP ports for the FOFB

Standardization





Stability test 8h (50 and 20 ppm spec.requirement)

DCCT1			
Setp	Imax	Imin	Delta-pp[PPM]
20	20.43935	20.43902	16.65

DCCT2			
Setp	Imax	Imin	Delta-pp[PPM]
20	20.45276	20.45240	17.95

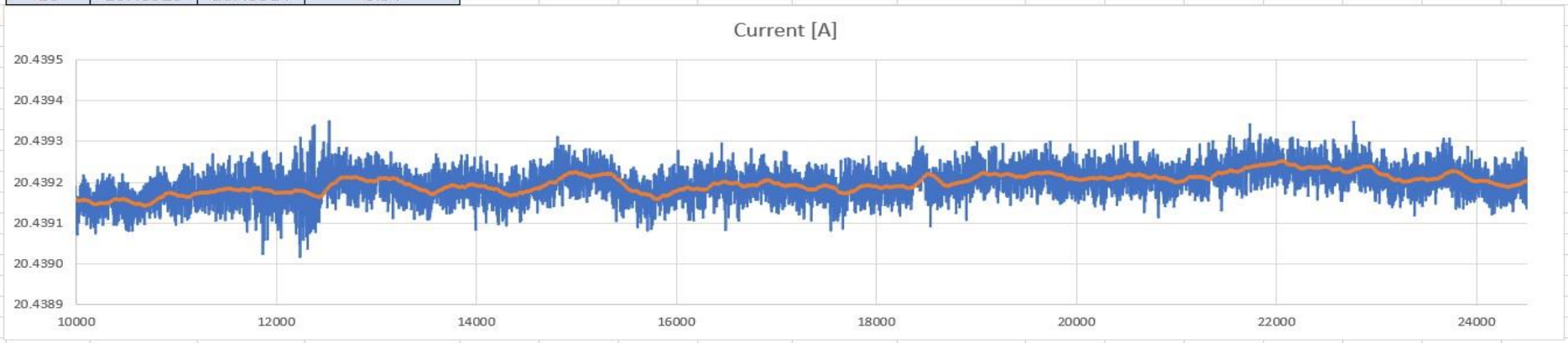
1048000

JS860R + 88001

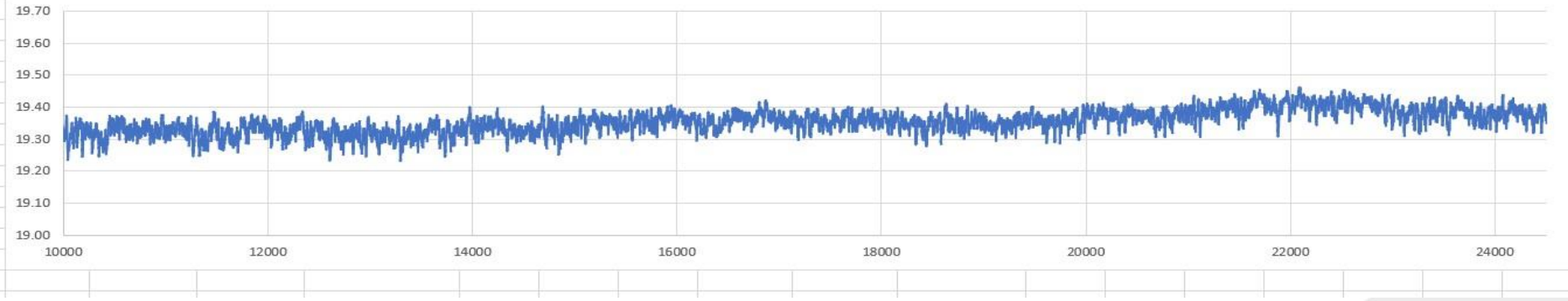
JS8

DCCT1 (Mov avg)			
Setp	Imax	Imin	Delta-pp[PPM]
20	20.43925	20.43914	5.54

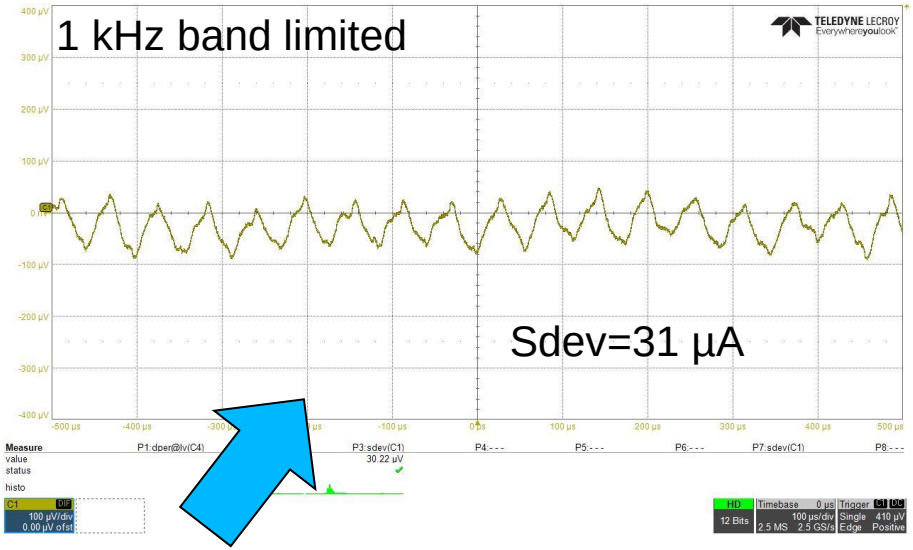
.0

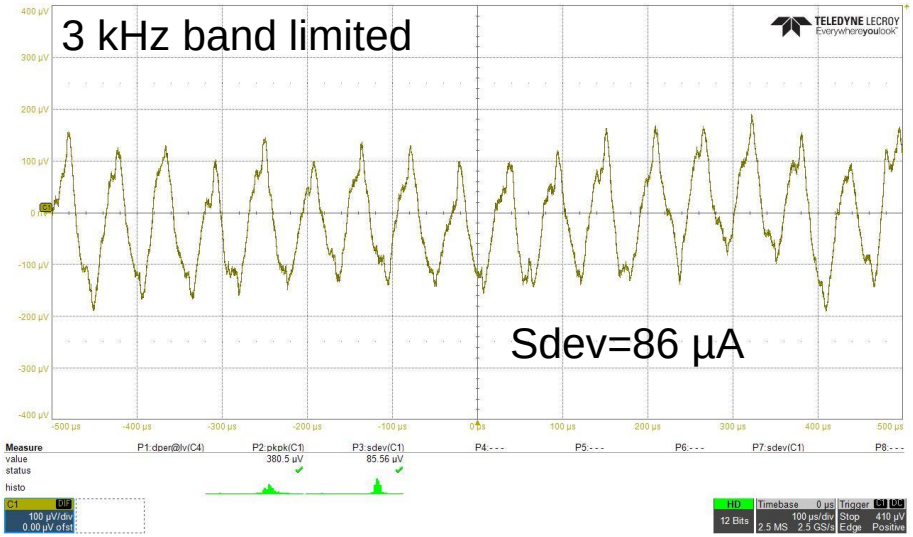


Temperature ['C]		
tmax	Tmin	Delta
19.46189	19.23142	0.23047



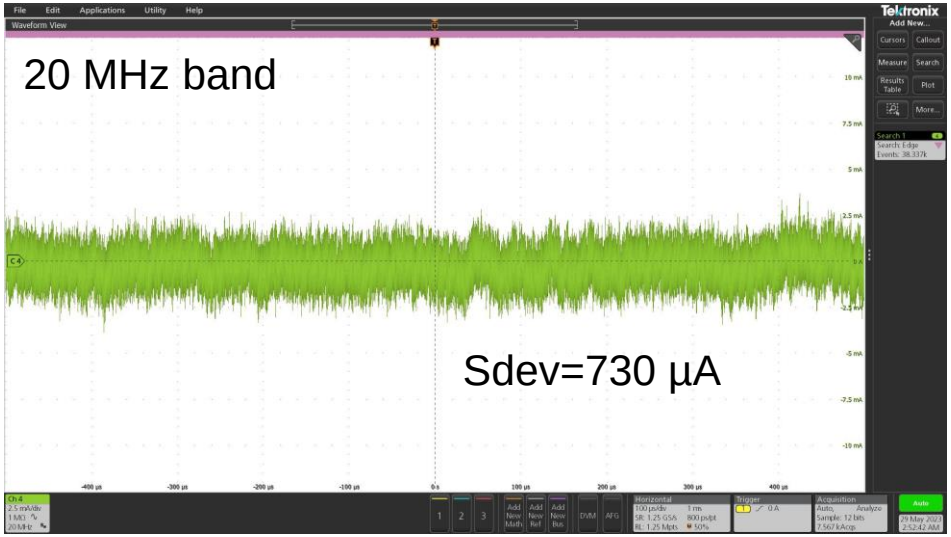
Current Ripple measurements @ 5 A_{dc}





residual noise from DCCT transducer

Miguel, how can we get rid of it?



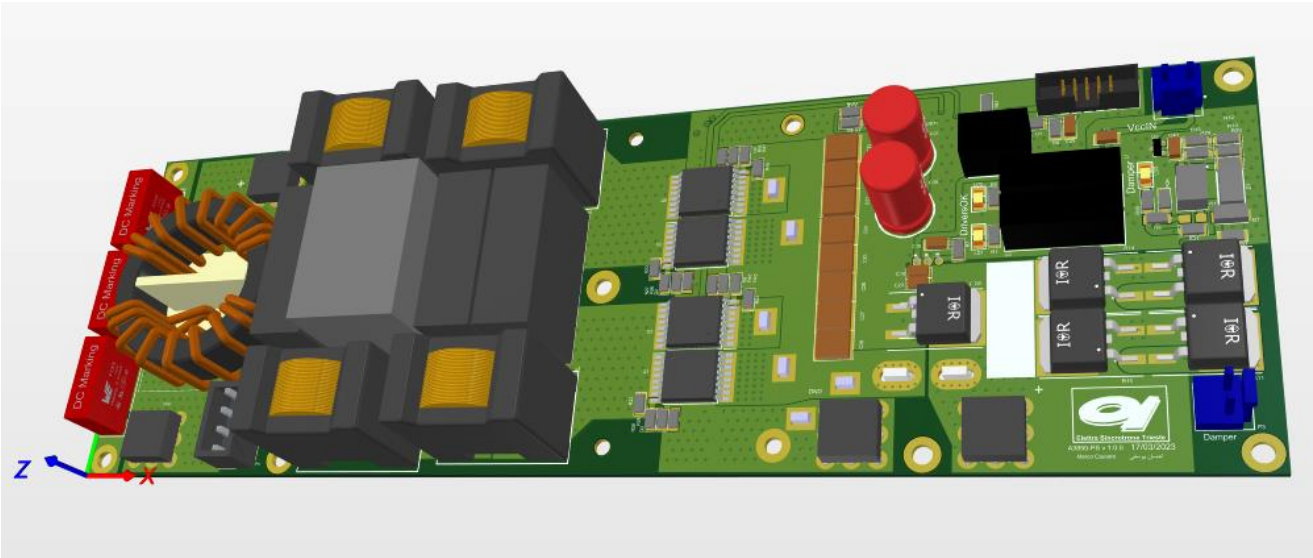
Standardization

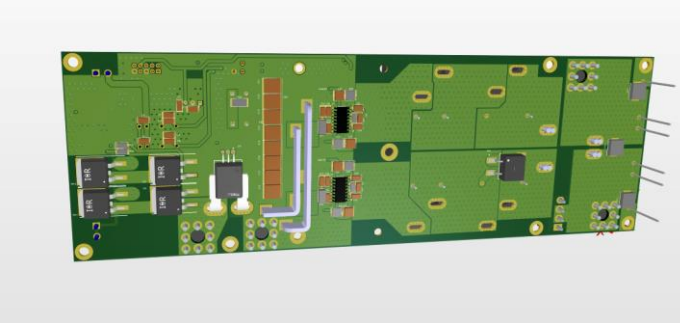
Multipoles:

in-house development, about 75% of all power supplies.

Expected size is 2U high.

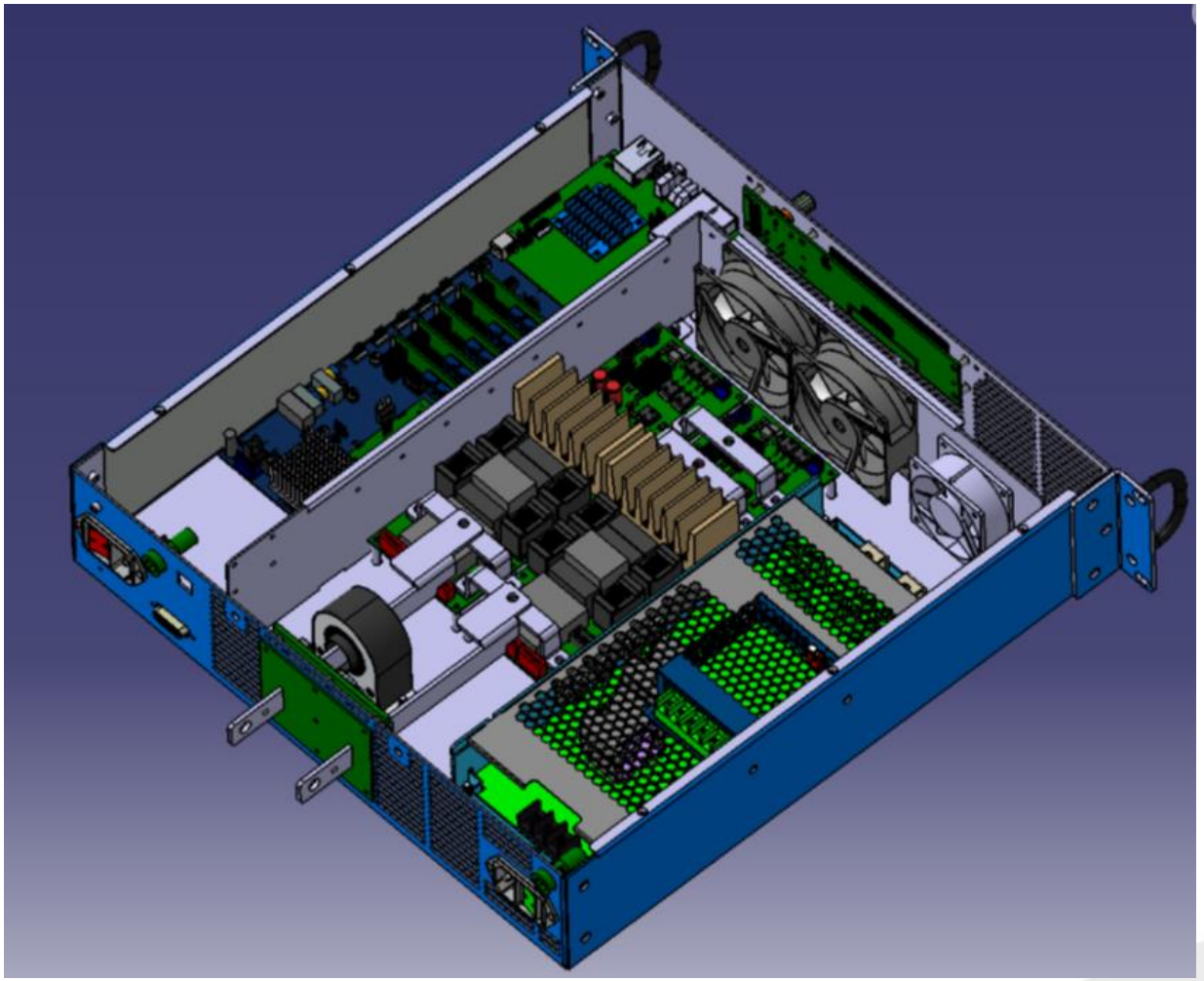
It uses two converters of the same kind of the corrector power supplies, 4th order output filter, f_s=100 kHz, interleaved drive





Standardization

Multipolar 4-Q power converter 100 A



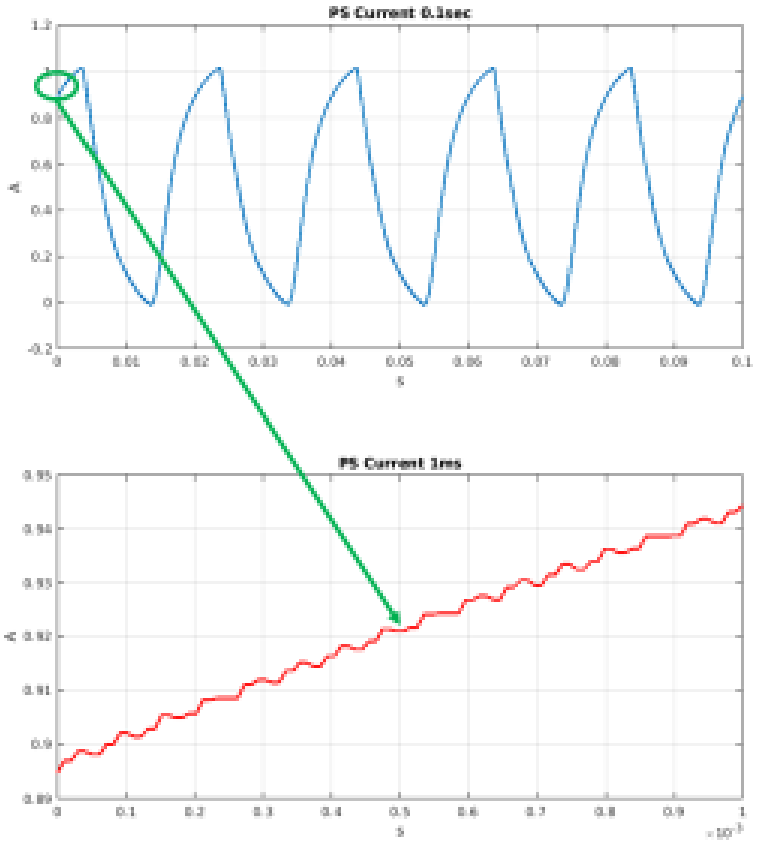
Waiting for the power parts to be delivered

Fast Link PS
(courtesy G.Gaio controls group)

https://accelconf.web.cern.ch/icalepcs2019/papers/mopha044.pdf

An article will be presented at ICALEPCS2023

Fast Link PS



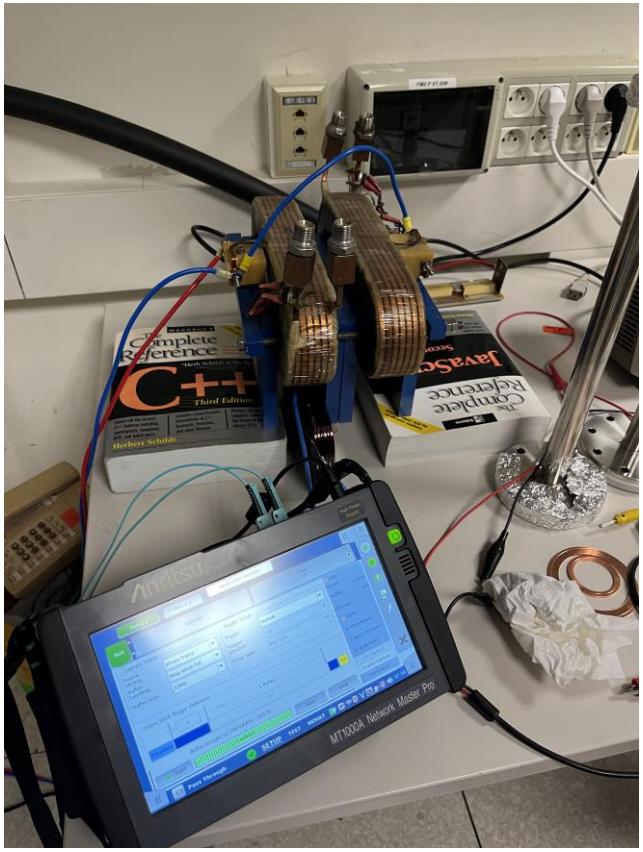
Fast link setting rate: 100kHz

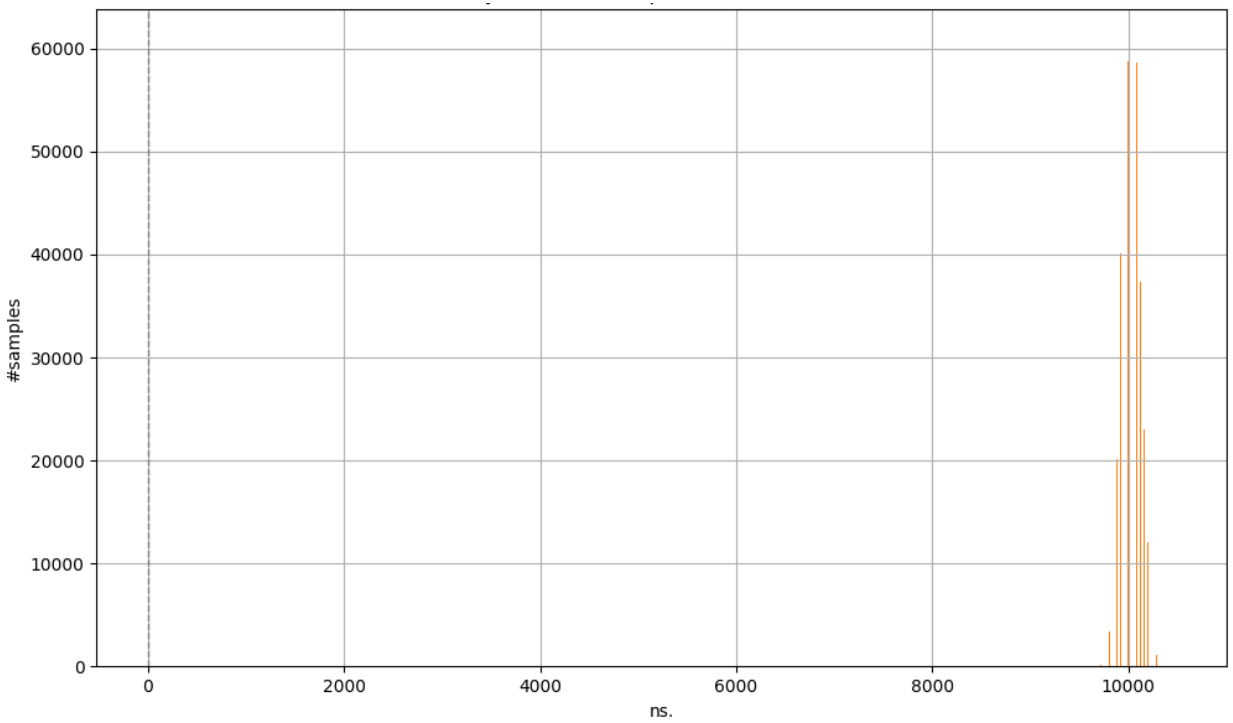
60Hz square waveform on old magnet, PID not optimized

PS follows the setpoint

The magnet has 30mH inductance

Fast Link PS





TOF Ethernet packet Jitter measured by an external analyzer configured in pass-through at 100 kHz setting.
Period: **10000 ns +/-100 ns**
(hard real-time PS setting)

Reliability/Availability **RA**MI

Reliability is achieved with a sound design of the device
Availability is defined as:

$$PS\ Availability = \frac{Actual\ Operable\ Time}{Expected\ Operable\ Time}$$

Operable time depends on:
MTBF, number of operating devices, MTTR (recovering operation from a faulty device).

Redundancy increases the operable time but:

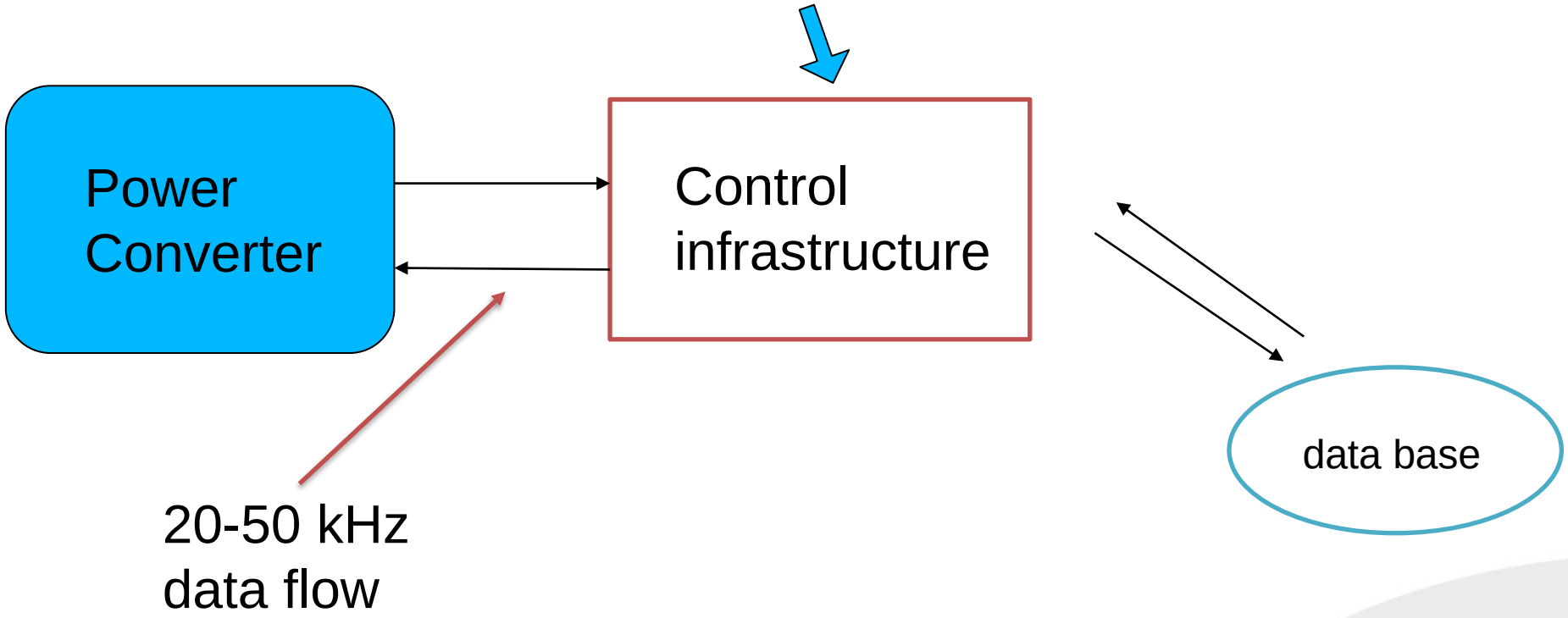
- *modules, cost and complexity increase*
- *increase of "volume"* (space is also critical @ Elettra 2.0)

so…

Reliability/Availability **RA**MI continued

System Prognostics

System Fault Prediction
using machine learning tools
instead of redundancy



Maintainability RA**M**I

Any faulty in-house designed unit will be repaired in the laboratory.

Faulty units are easy to fix, having the same control and regulation cards both for the 100 A and the 25 A types.

This helps manage the spares **in numbers, types and budget**.

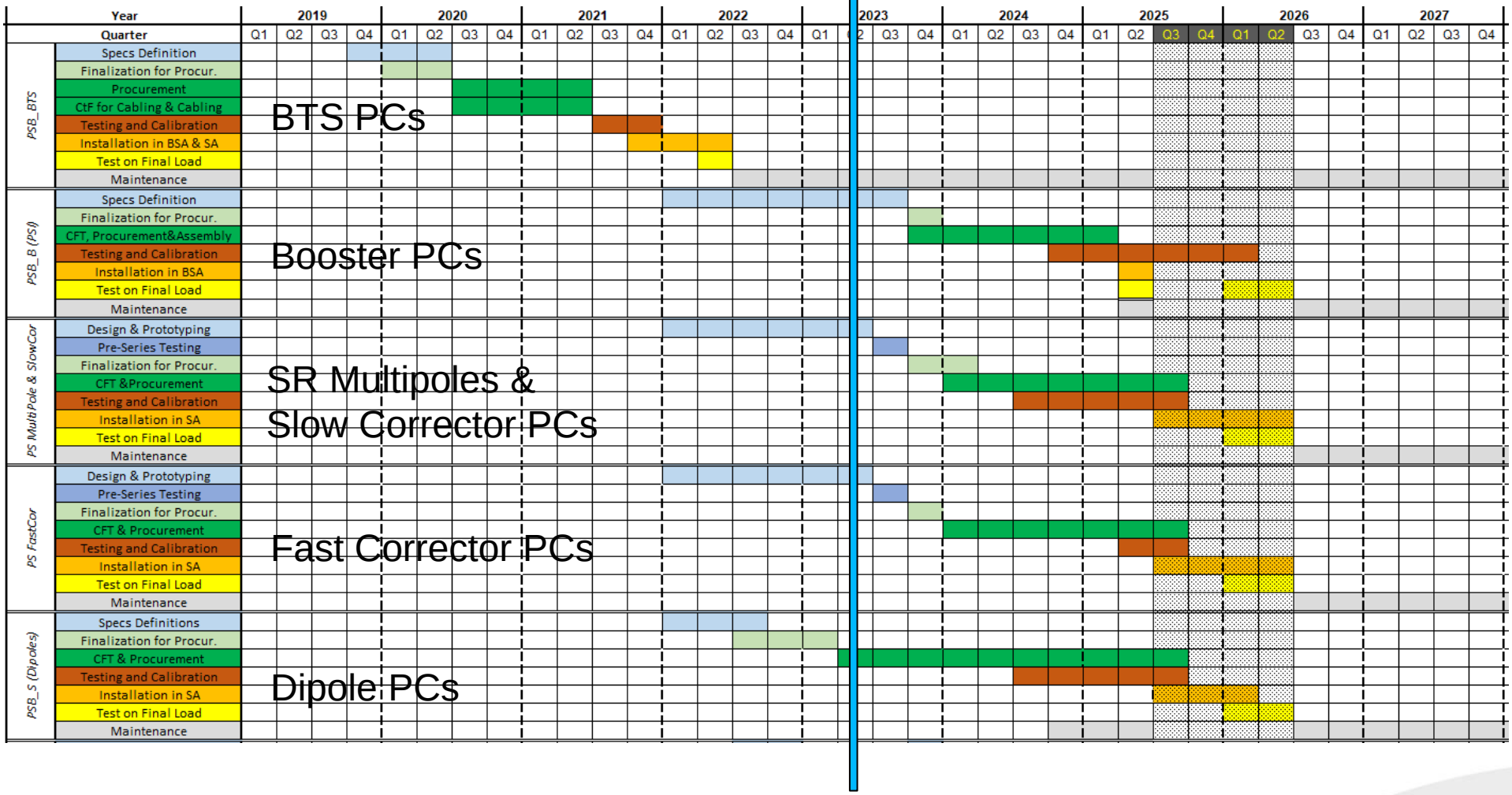
Inspectability RAMI

The power supplies shall be equipped with local display and remote diagnostics, as well.

Status of the power supplies should be easily accessible
Unambiguous indication on the operability of the power supplies and, in case, describing the fault(s) preventing operations.

Separate AC mains from UPS for the control part:
in case of a power failure the control of the power supplies remains responsive.

Schedule


Today
Year
2019
2020
2021
2022
2023
2024
2025
2026
2027
Quarter
Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4
PSB_BTS
Specs Definition
Finalization for Procur.
Procurement
CtF for Cabling & Cabling
Testing and Calibration
Installation in BSA & SA
Test on Final Load
Maintenance
BTS PCs
PSB_B (PSI)
Specs Definition
Finalization for Procur.
CFT, Procurement&Assembly
Testing and Calibration
Installation in BSA
Test on Final Load
Maintenance
Booster PCs
PS MultiPole & SlowCor
Design & Prototyping
Pre-Series Testing
Finalization for Procur.
CFT &Procurement
Testing and Calibration
Installation in SA
Test on Final Load
Maintenance
SR Multipoles &
Slow Corrector PCs
PS FastCor
Design & Prototyping
Pre-Series Testing
Finalization for Procur.
CFT & Procurement
Testing and Calibration
Installation in SA
Test on Final Load
Maintenance
Fast Corrector PCs
PSB_S (Dipoles)
Specs Definitions
Finalization for Procur.
CFT & Procurement
Testing and Calibration
Installation in SA
Test on Final Load
Maintenance
Dipole PCs

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