PAUL SCHERRER INSTITUT

Power Electronics-Engineering :: Paul Scherrer Institut

SLS2 – from a new Lattice to a Power Supply Concept

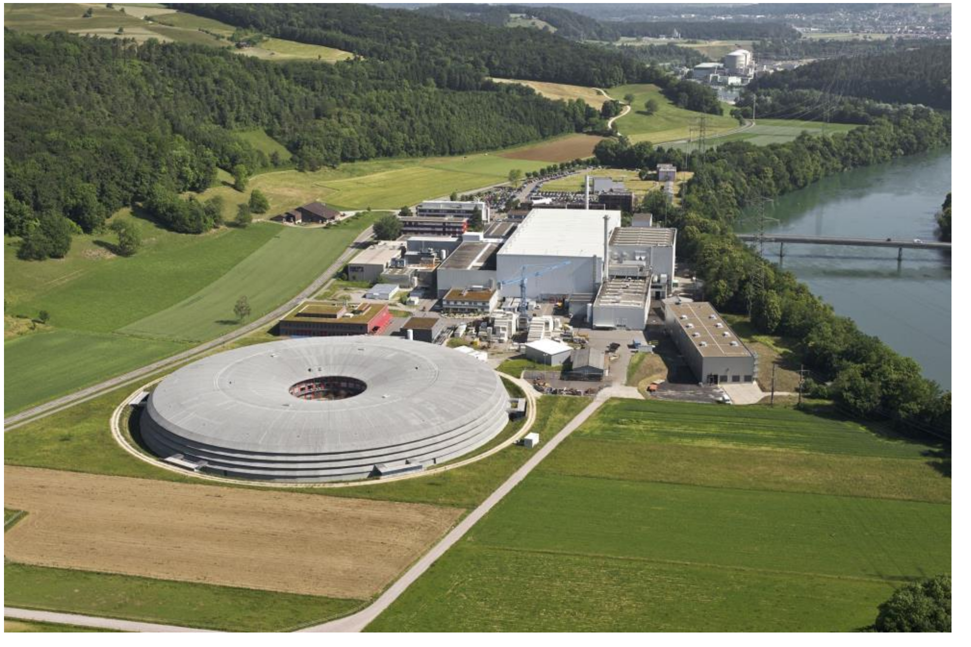
Presentation @ POPCA 2018, Campinas (Brasil)

Agenda

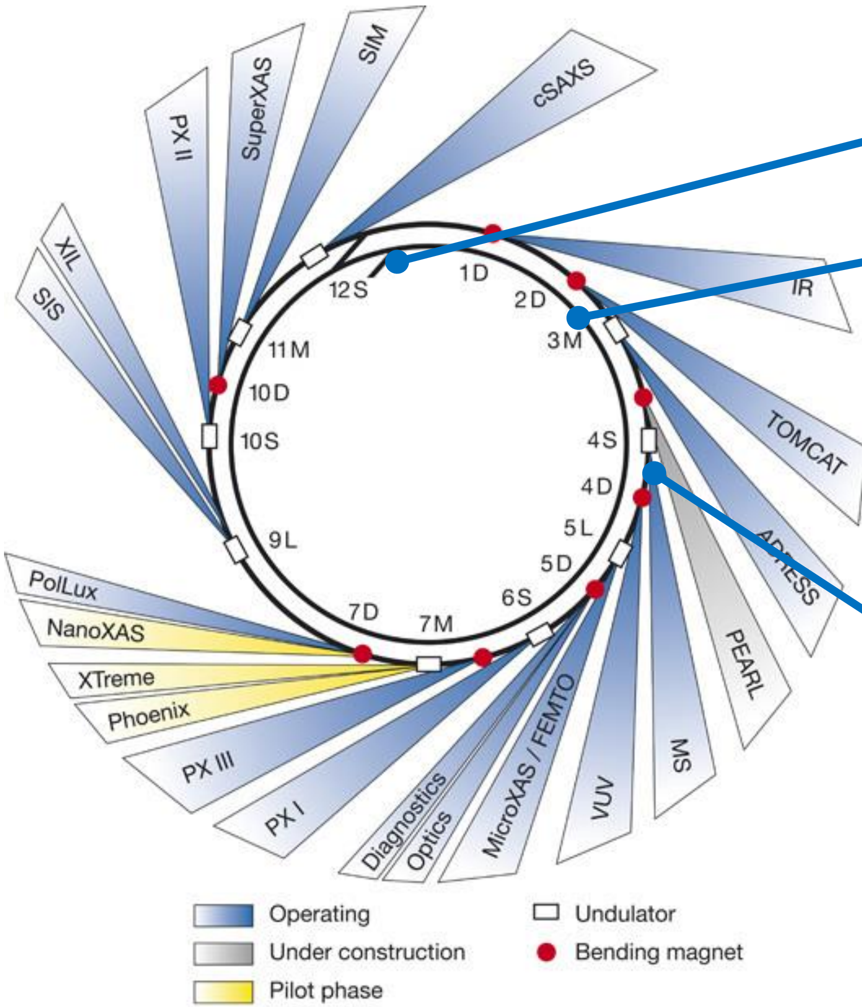
- SLS
- The SLS2 project: A new storage ring for SLS
- SLS2 storage ring lattice
- Rating and number of power supplies
- Requirements for power supplies
- How to cover SLS2 needs with as few power supply designs as possible
- XSPS
- 50 A design
- PS for Superbends

Swiss Light Source SLS

- 3rd generation synchrotron light source
- 2.4 GeV
- provides photon beams of high brightness for research in materials science, biology and chemistry
- In operation since 2000



The SLS2 project – a new storage ring for SLS



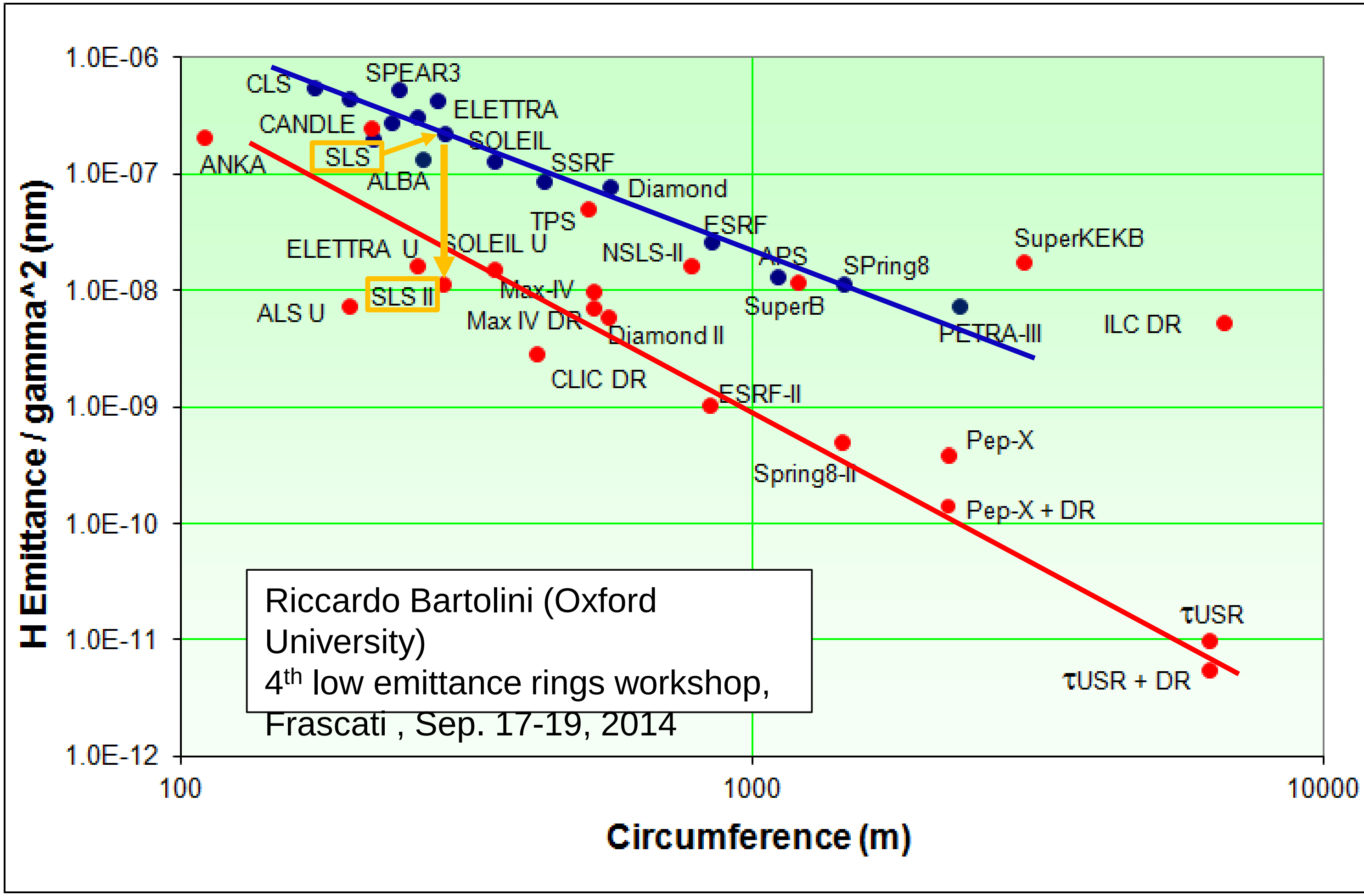
Linac

Booster

Remain unchanged in the SLS2-project

Storage-Ring:
A new storage ring will be built, planned commissioning 2024

SLS2 storage ring lattice



Storage rings in operation (•) and planned (•).

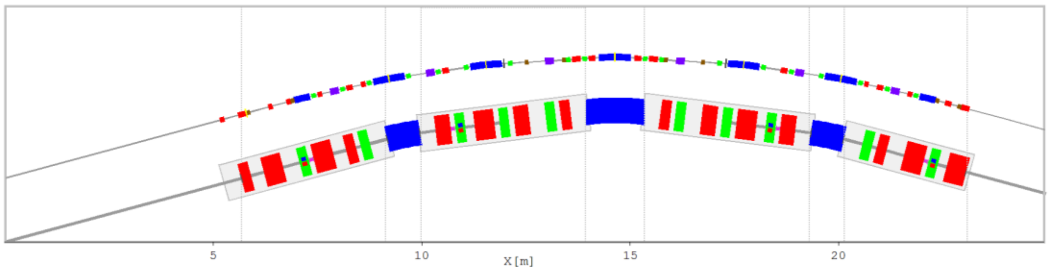
The old (—) and the new (—) generation.

Low emittance as main design parameter

$$\text{emittance } \varepsilon \propto (\text{energy})^2 \times (\text{bend angle})^3$$

- Total bend angle in ring is always 360°
- Distribute angle to more magnets
  → Smaller deflection angle per magnet
- Emittance can be reduced with (# bending magnets)^2 (=n^3/n)

SLS2 storage ring lattice



SLS2 storage ring lattice

SLS storage ring lattice

- More magnets
- Smaller deflection angles

SLS2 storage ring lattice

Magnet	#	Magnet excitation	Remark
Bending magnet triple BN-VB-BN	60	Permanent magnet	Later, 3 of these will be replaced by superconducting magnets
Anti-bend AN	120	Permanent magnet	
Sector end bend BE	24	Permanent magnet	
Sector end anti-bend ANM	24	Permanent magnet	
Quadrupoles QC	96	50 A, 1Q	
Sextupole SX	288	50 A, 1Q	On combined Sextupole / Octupole building block magnet SOQ
Octupole OC	288	50 A, 4Q	On SOQ
Aux. Quadrupoles QA	288	5A, 4Q	On SOQ
Skew quad windings	96	5A, 4Q	On SOQ, evlt. later more of these will be installed
Corrector magnets	240	5A, 4Q	120 horizontal, 120 vertical

Rating and number of power supplies

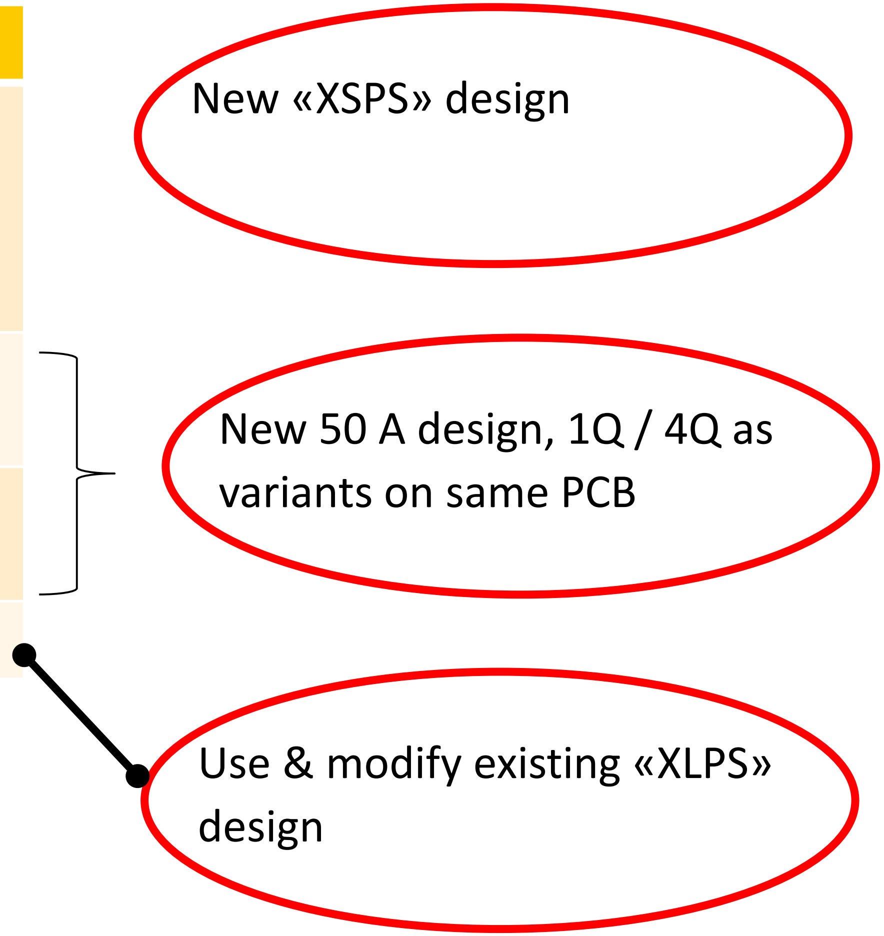
PS rating	1Q /4Q	#	Magnets / connection
5 A, 24 V	4Q	864	Corrector magnets Aux Quadrupoles Skew Quadrupoles
50 A, 72 V	1Q	168	Quadrupoles Sextupoles, 72 groups / 4 in series
50 A, 50 V	4Q	12	Octupoles, 12 groups / 24 in series
400 A, 50 V?	2Q	3	Superconducting, with Quench circuit
Total		**1074**	

For comparison: # Power supplies in SLS storage ring: 391

(although many magnets in SLS2 are permanent magnets)

How to cover needs with as few PS-designs as possible

Magnets / connection
Corrector magnets Aux Quadrupoles Skew Quadrupoles
Quadrupoles Sextupoles, 72 groups / 4 in series
Octupoles, 12 groups / 24 in series
Superconducting, with Quench circuit



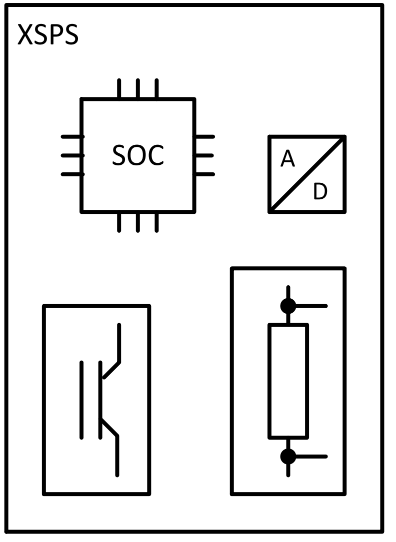
New «XSPS» design (extra small PS)

Key features

- Shunt based current measurements
  Low-noise (<10 ppm RMS) high precision measurement
  Small size, low price (no DCCT needed)

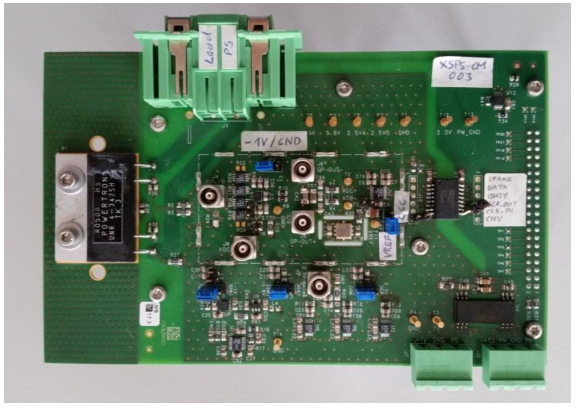
- Processor and power part on same board
  Short distances for low EMC, compact in size.

- Power part with GaNi FETs
  500 kHz PWM carrier frequency, low losses



XSPS status

Shunt current measurement



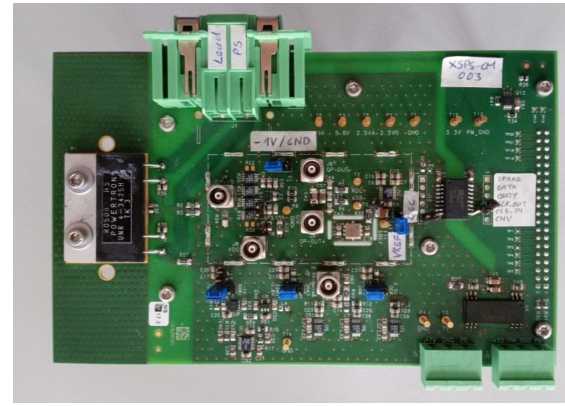
Performance of shunt current measurement tested with dedicated test-board.
Ripple & noise < 10 ppm RMS

Power part

Power part and all voltage measurements are currently tested on a test-board.

Shunt current measurement

Using a shunt current measurement instead of a DCCT-based measurement:



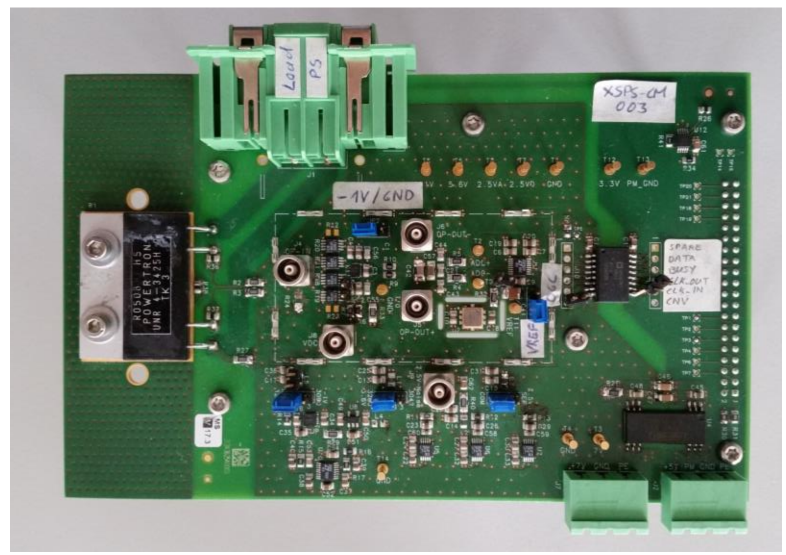
- Saves space
  Only few cm^2, can well be integrated on the XSPS directly.
  DCCT was a seperate PCB with the DCCT «brick» on top.

- Saves money
  around CHF 100 instead of CHF 500 per measuring channel

- Also, no DCCTs available for < 10 A

Shunt current measurement

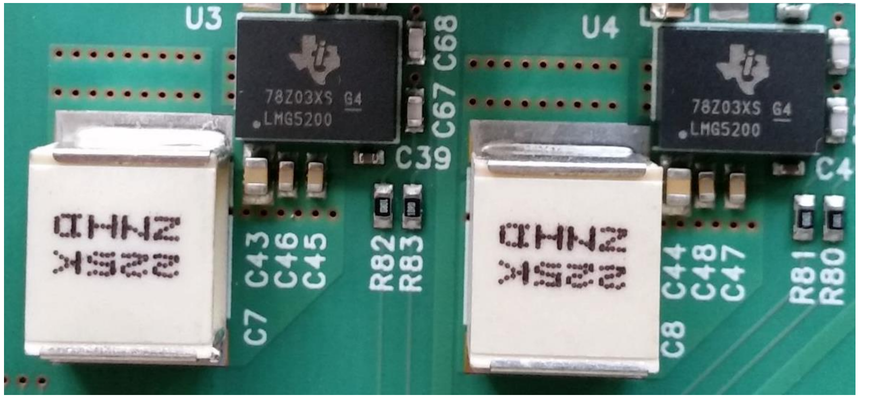
- Using best available differential OpAmp and ADC for maximal signal quality:
  - LTC2378-20 ADC:
    20 bit, 1Msps
  - LTC6363 precision OpAmp
    Typ 20 ppm gain error



XSPS status

Power part

- TI LMG5200 GaN-FET Modules work fine
  @ fPWM=500 kHz, 5 A



- DM-Filter stage results in only 4.5 mV pk 1 MHz component in u_{Load}

- CM-Filter damping clearly less than designed:
  CM-choke has nasty parasitic effects, mainly parallel R of ca. 600 Ohm

- Voltage measurements successfully tested, work as designed

- Current measurement with shunt confirming measured noise < 10 ppm RMS

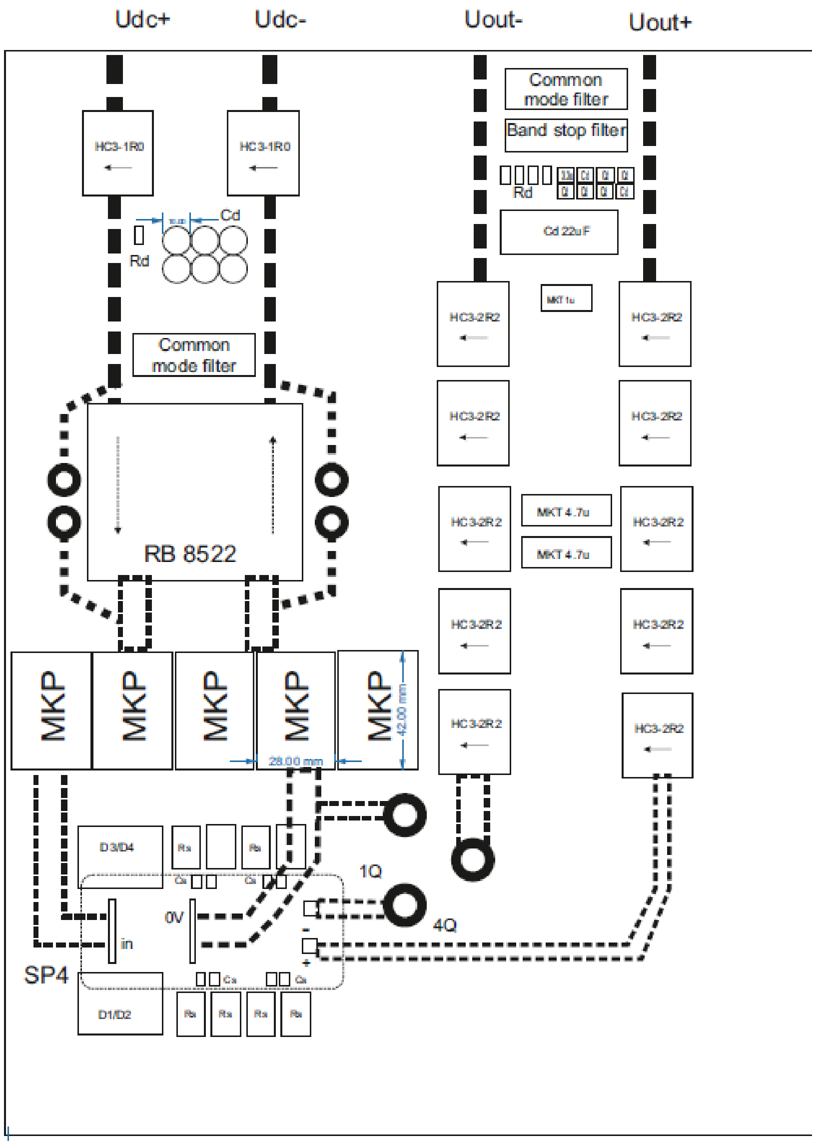
Controller

The controller for our new power supplies
will be based on Xilinx Ultrascale+ SOM

To get experience, the control for the
5A power part test board has already been done
with such a SOM (and an eval-board).

Using a SOM, we do not have to do the (very demanding) design & layout of the processor-close circuits:
Memory, power supply and communication interfaces are already provided.

50 A PS concept



- PCB to be built horizontally into a 19’’ rack
(including controller card)
- One common design for 1Q, 4Q (FETs and CM-Filter as mounting variants)
- Schematic for prototype currently in work

50 A PS concept

50 A converter has to cover:

• Quadrupoles :	96 pcs,	50..70 A,	50 V,	1Q
• Sextupoles series connection:	72 circuits,	50 A,	72 V,	1Q
• Octupoles series connection:	12 circuits,	50 A,	50 V,	4Q

Developping an extra converter design for the only 12 4Q pcs would not be efficient

→ Trying to cover both 1Q and 4Q with one design

→ Making 1Q as mounting variant (less FETs, no CM-choke) saves money - most pcs. are 1Q

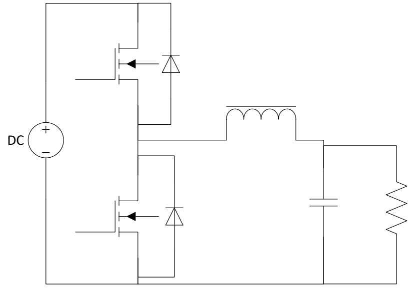
Converter topology	4 Q – 50A	1Q – 50A	1Q – 70A
Output current	50 A	50 A	70 A
DC link voltage	72 V	72 V	28 V
Output voltage	50 V	50 V	24 V
Max mod. Index	72 %	72 %	86 %
load resistance range	0.3 - 1 Ω	0.3 - 1 Ω	0.1- 0.4 Ω
Max input current	37.3 A	37.3 A	61 A

50 A PS concept

On the 50 A converter, we intend using Microsemi FET modules.
To cover 1Q and 4Q on the same design, the following modules (in the same case) are planned:

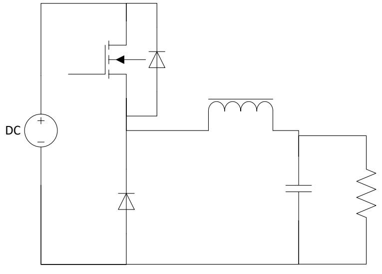
<u>1Q:</u>

APTM20AM08FTG



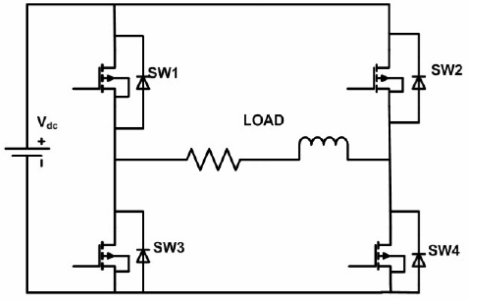
or

APTM20SKM08TG



<u>4Q:</u>

APTM20HM16FTG



For all:

f_{Switch}=100 kHz

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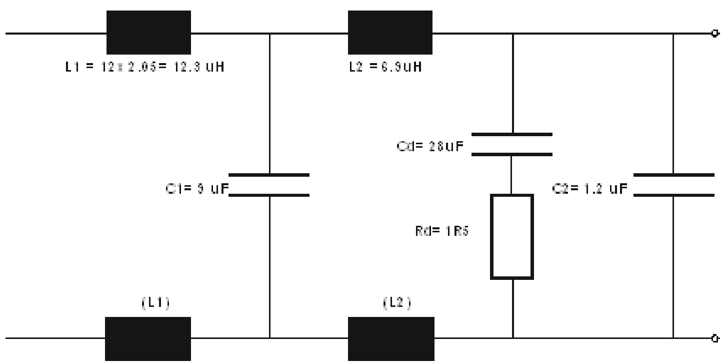
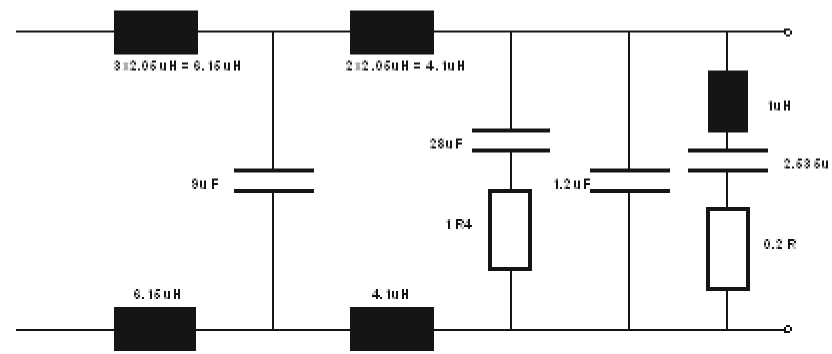
50 A PS concept

The resulting output frequency is for 4Q 2*f_{PWM}, for 1Q only 1*f_{PWM}

To reach the same filter damping, the 1Q filter uses a notch filter at the output (a first for us – simulations look good).

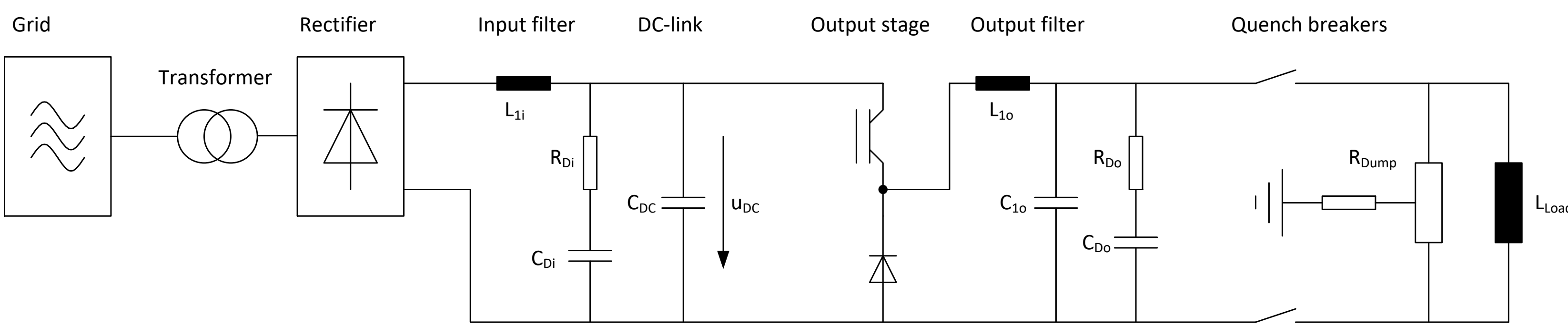




PS for superbends

In an upgrade programme after initial commissioning, 3 of the 60 bend-magnets will be replaced by superconducting magnets.

The rating is not fully clear yet – expected approx. 400 A, max. 50 V
Planned is to use our «XLPS» design, together with a quench circuit.

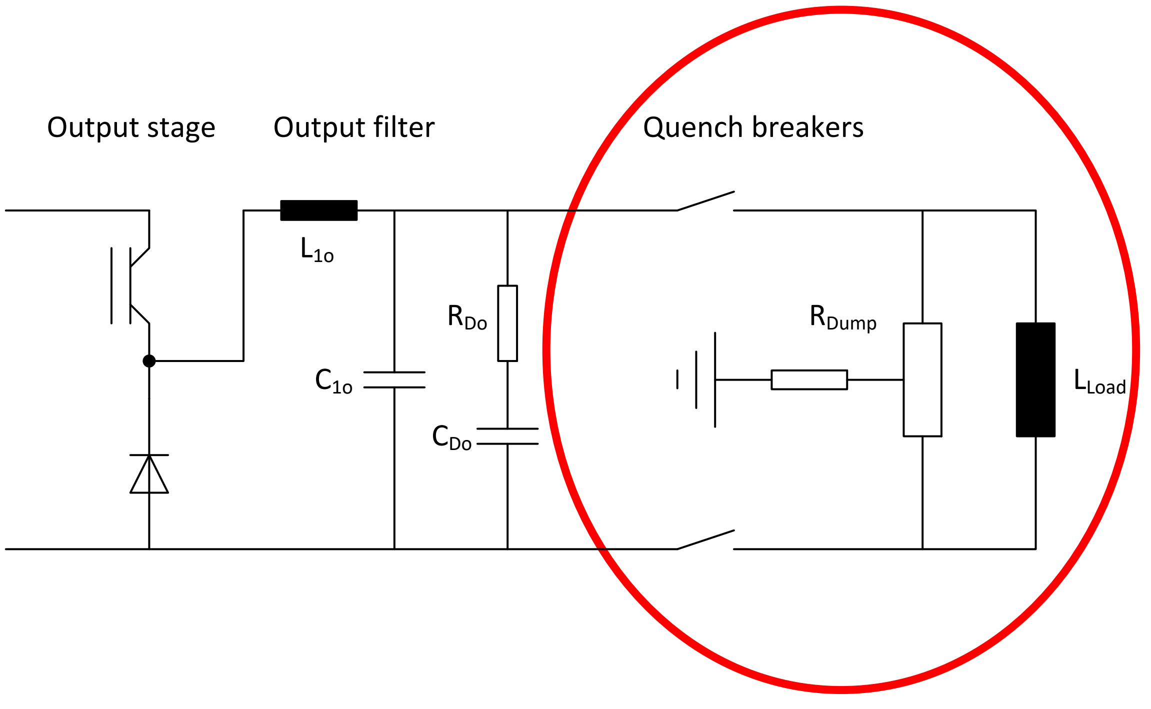


PS for superbends

Quench circuit

Purpose: Quickly reduce the current of the coil and absorb the energy in case of a quench .

R_{dump} is in the order of magnitude of some few Ohms.
Since R_{dump} >> R_{coil}, it does not matter if it is always in circuit.

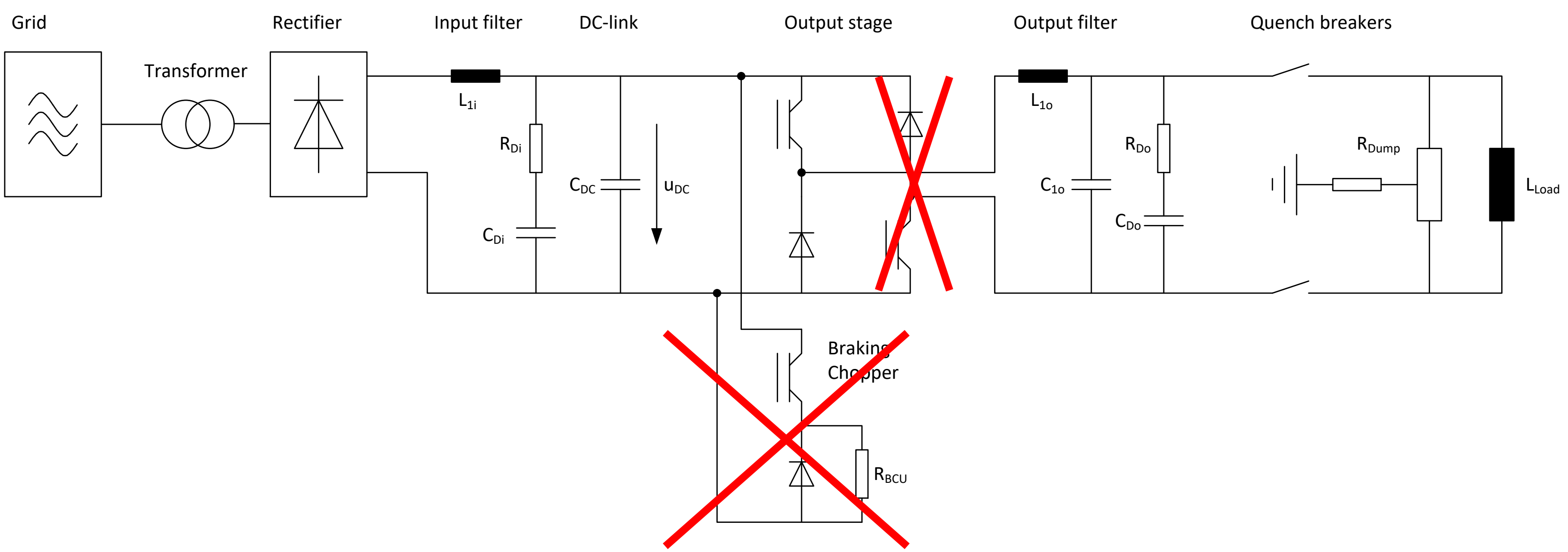


PS for superbends

<u>«Braking» chopper</u>

For other applications with superbending magnets, the necessity of a braking chopper has been discussed to dissipate the energy of the magnet coil when reducing current.

For the superbends, this is not needed. The magnet design is such that the current can only be reduced very slowly.



PS for superbends

<u>XLPS impression / example:</u>

Power supply for AHB magnet

- 1200 A / 200 V
- Infineon IGBTs
- f_{SW}=20 kHz

Some remarks

- The lattice is not as stable as it should for our schedule. Latest changes have been made as late as in Sept

- Magnet design is being done now. Magnet data is sometimes quite a bit away from first estimations.
  e.g. it seems now 50 A is from magnet side not an optimal choice, but 150 A would be better.

→ The concepts for the whole ring, lattice and magnets has not settled yet – and so neither the power supply concept (although we already have put considerable development effort into it).

→ We need to stay flexible

Wir schaffen Wissen – heute für morgen

Questions?
Please ask.