Breaking news from SOLEIL
+ Some reflections on the main topic

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5th POCPA Workshop, 24-26 May 2016, ALBA

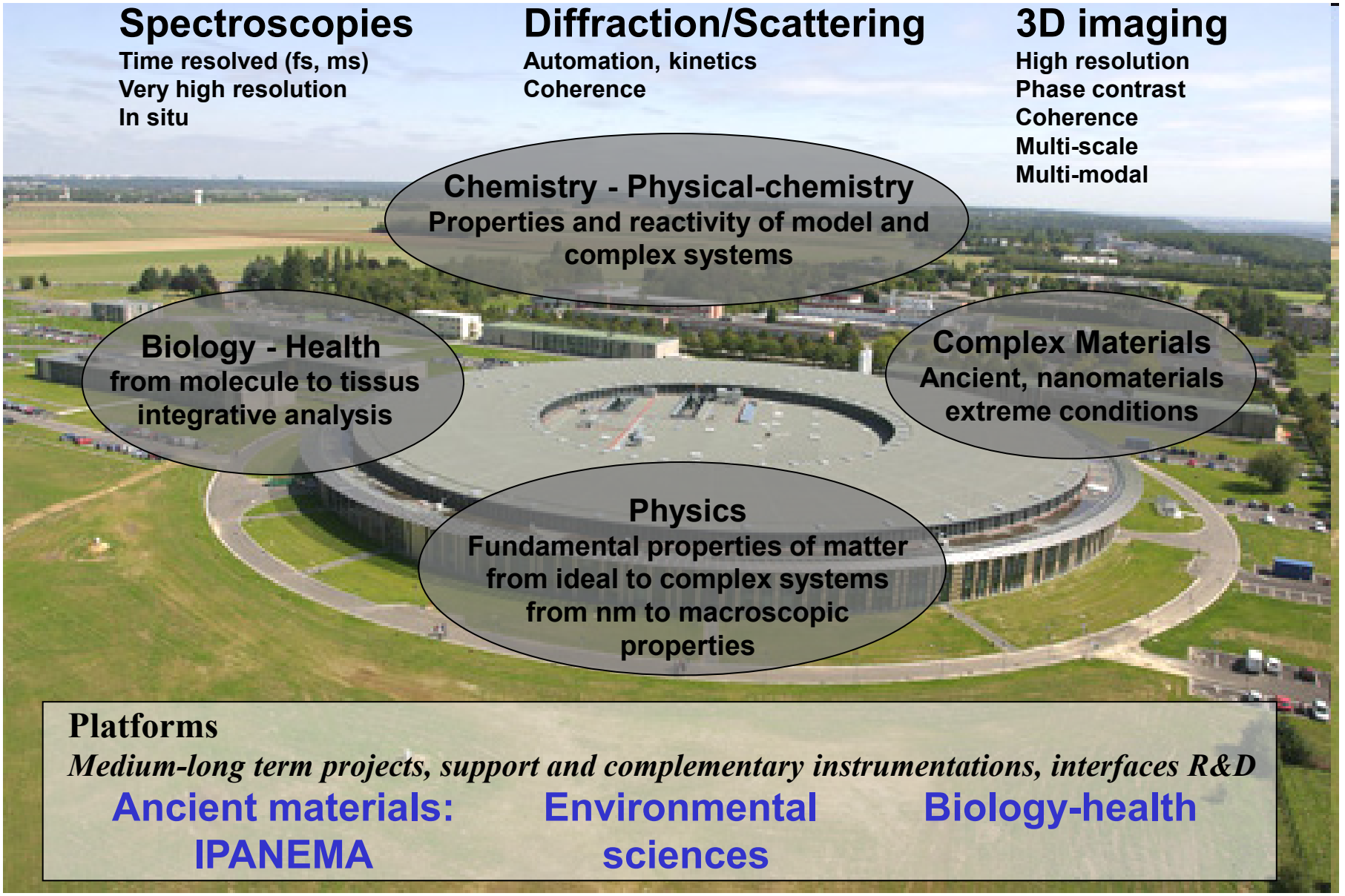
Some words about SOLEIL

SYNCHROTRON SOLEIL: A SCIENCE PLATFORM

Beamline operation:
Fast growing nb. of light sources

2008: 11 BL
2009: 14 BL
2010: 17 BL
2011: 20 BL
2013: 25 BL
2014: 27 BL
2016: 29 BL

Some words about SOLEIL



Some words about SOLEIL

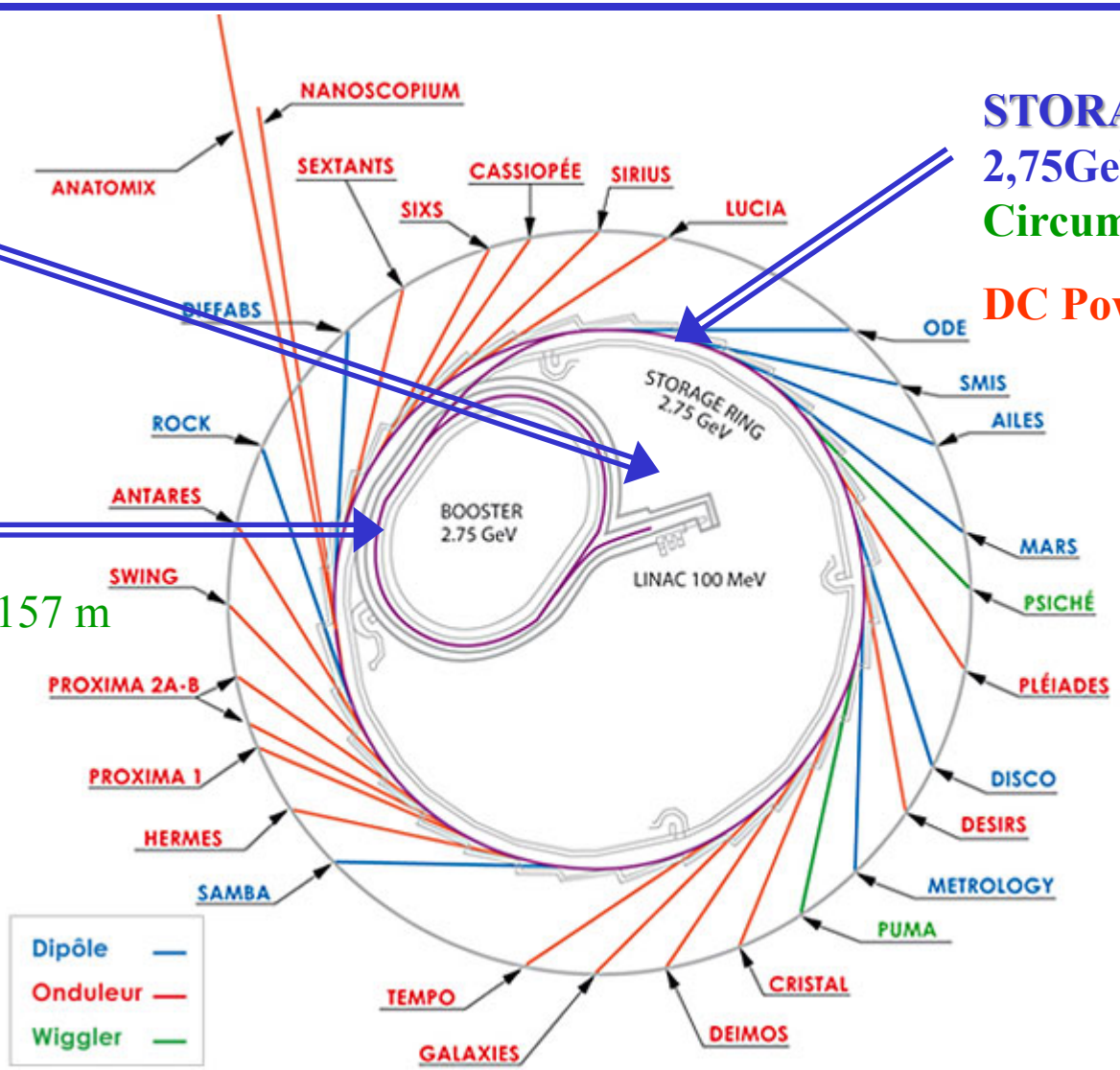
LINAC
110 MeV
3 Hz rep. rate

BOOSTER
Full Energy
2,75GeV
Circumference: 157 m

Power supplies cycling at 3 Hz

STORAGE RING
2,75GeV
Circumference: 354 m

DC Power supplies

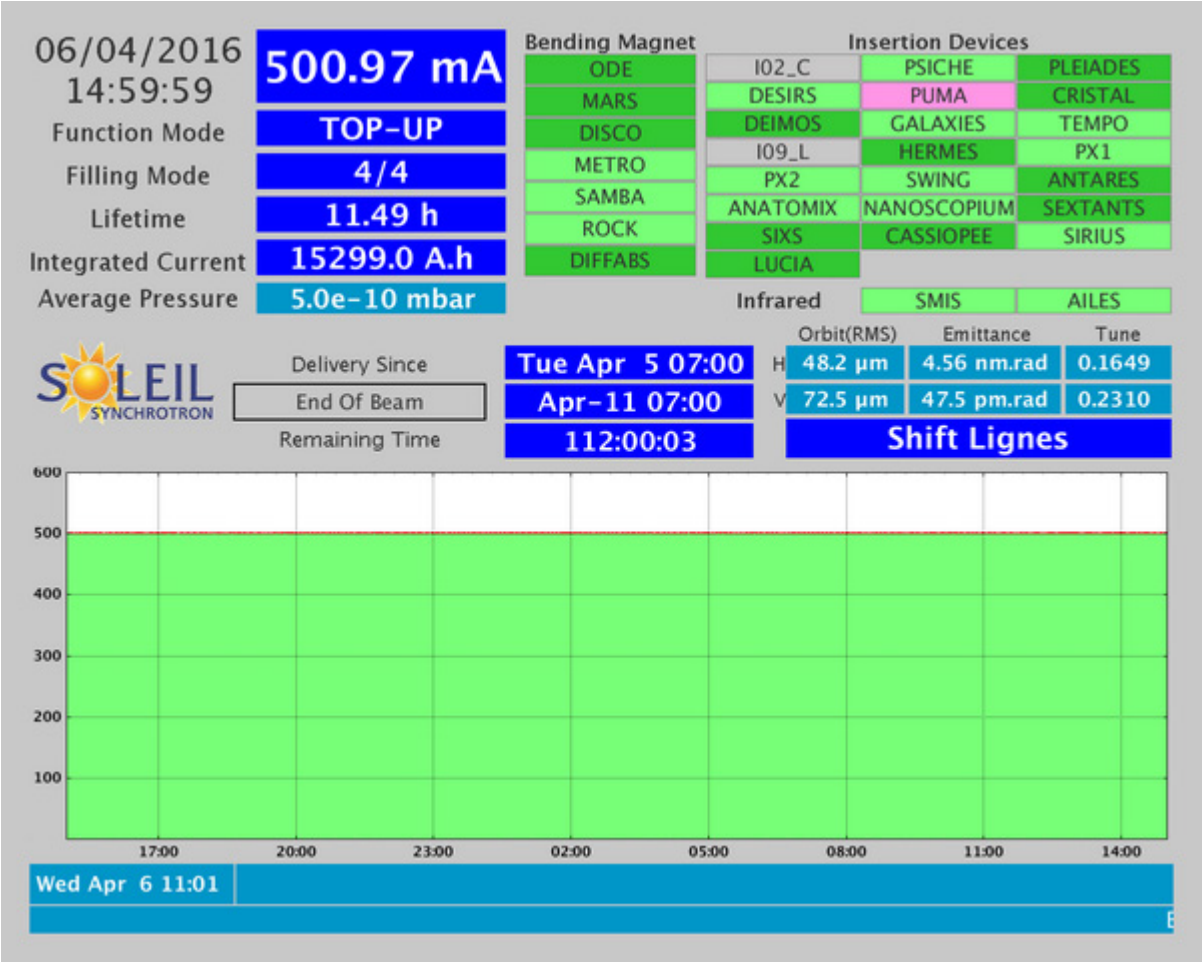


- About 600 magnet power supplies installed
- Linac and Booster designed for Top-up operation

Some words about SOLEIL

Routinely operation @ 500mA (max. current for which the machine has been designed) since December 2015

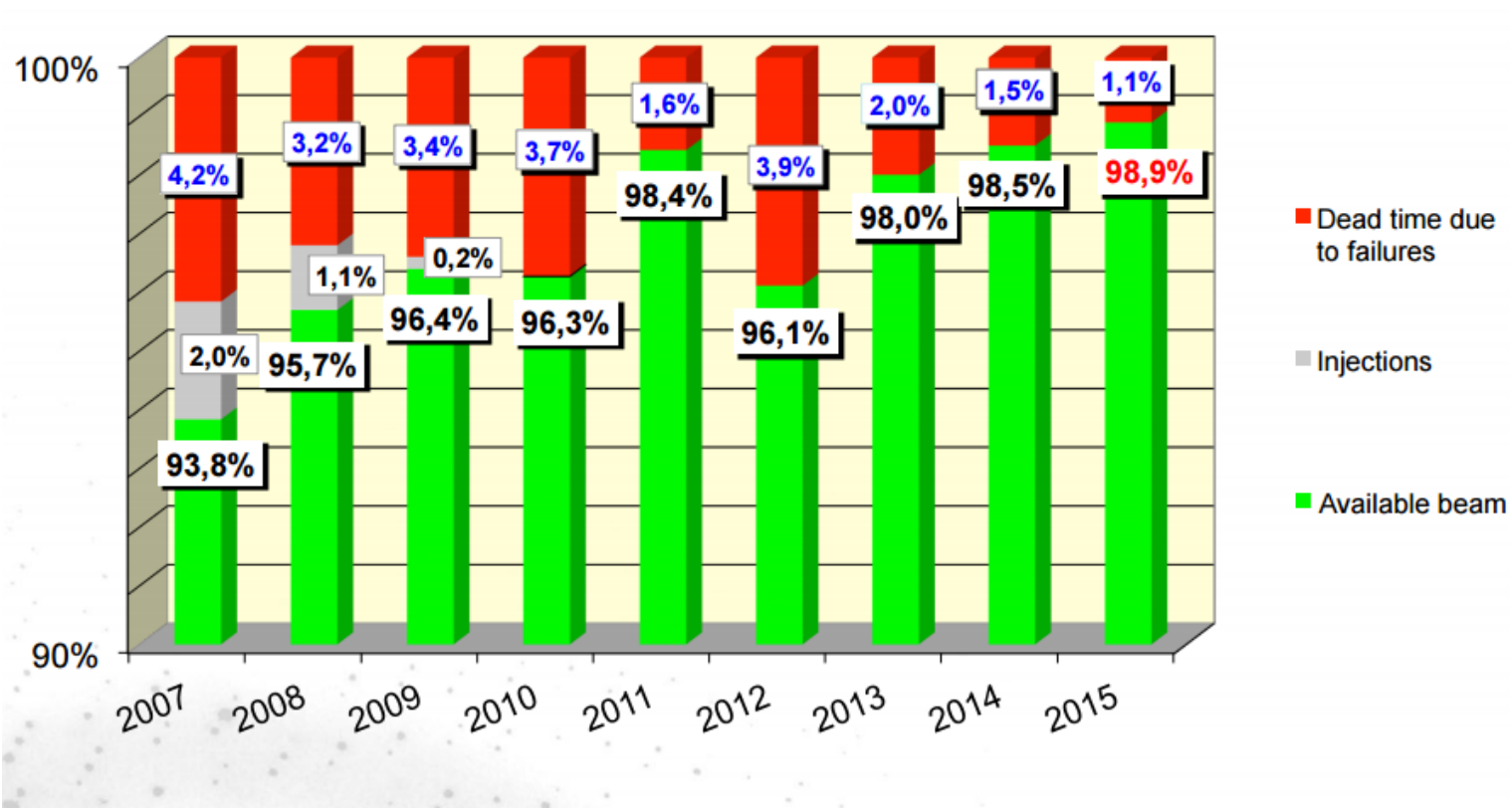
Intensity constant within 1% (Top-Up)



Machine status

Some statistics

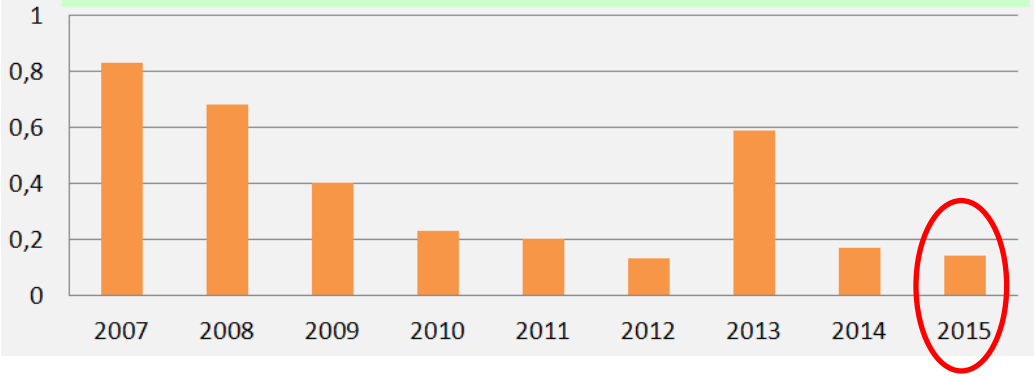
- **In 2015:**
  - **User beam availability: 98,9%** (= 4904 hours of beam delivered to users)
  - **MTBF: 105,3 hours**
  - **MTTR: 1h10**



Some statistics

- **In 2015:**
  - **Major incident in May:** 3 weeks of beam interruption due to a fire outbreak in a reactive power compensator system
  - **Consequence:** Beam schedule changed → Shorter machine shuntdowns (nearly no maintenance possible during the 2nd semester)
  - **Good reliability & availability on the power supplies**

Percentage of dead time due to power supply failures over the total operational time of the synchrotron



6 incidents in 2015

~ 7 hours of dead time

But 4 hours wasted following a failure of the main dipole PS:

- Normal procedure: switch the load on the spare dipole PS
- Pb: The colleague on-call didn't realize there is a neutral position on the changeover switch…
- Failure occured at the end of his night shift → Tough!
- Written procedure should have been more detailed…

Some statistics

- **In 2016 until May:**
  - **User beam availability: 99,7%**
  - **Not a single incident on the power supplies**

Focus on 2 events

1/ Booster PS:

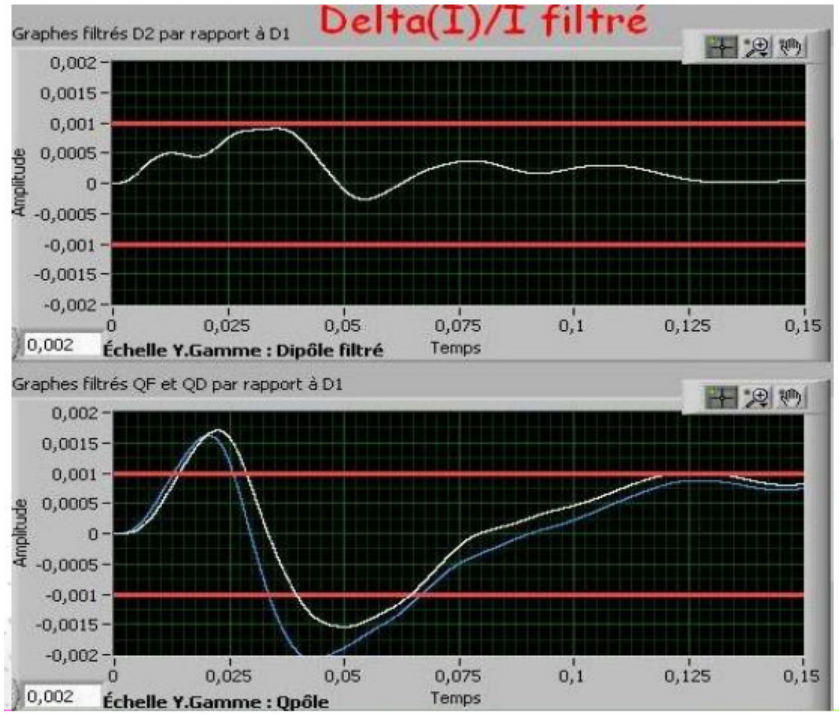
> May 2015: Slow drift of the beam position in the transfer line between Booster and Storage Ring ⇒ Need to change the current offsets / amplitudes of the Booster 3Hz PS from time to time

October: Situation gets worse (Need to tune the beam injection inside the Storage Ring every 2 or 3 days)

⇒ A dedicated machine shift is scheduled

Result: There is a drift of the current fed by 1 of our 2 Dipole Booster PS:

Pb due to the PSI ADC/DAC card



Dipole 1 versus Dipole 2

QF, QD versus Dipole 1

Bad luck → Not detected in our « tracking tool » used to monitor the tracking between the 3Hz PS currents:

It was out of order since March (and unfortunately no time to repair it because of the shortening of the machine shutdowns decided after the fire outbreak)

Focus on 2 events

2/ Fire outbreak:

May 2015: 3 weeks of beam interruption due to a fire outbreak in a reactive power compensation cabinet

At SOLEIL, we have this kind of system installed on the main LV switchboards

⇒ Occured on a 540 kVAR capacitor bank connected to the switchboard supplying the cooling tower systems

New developments

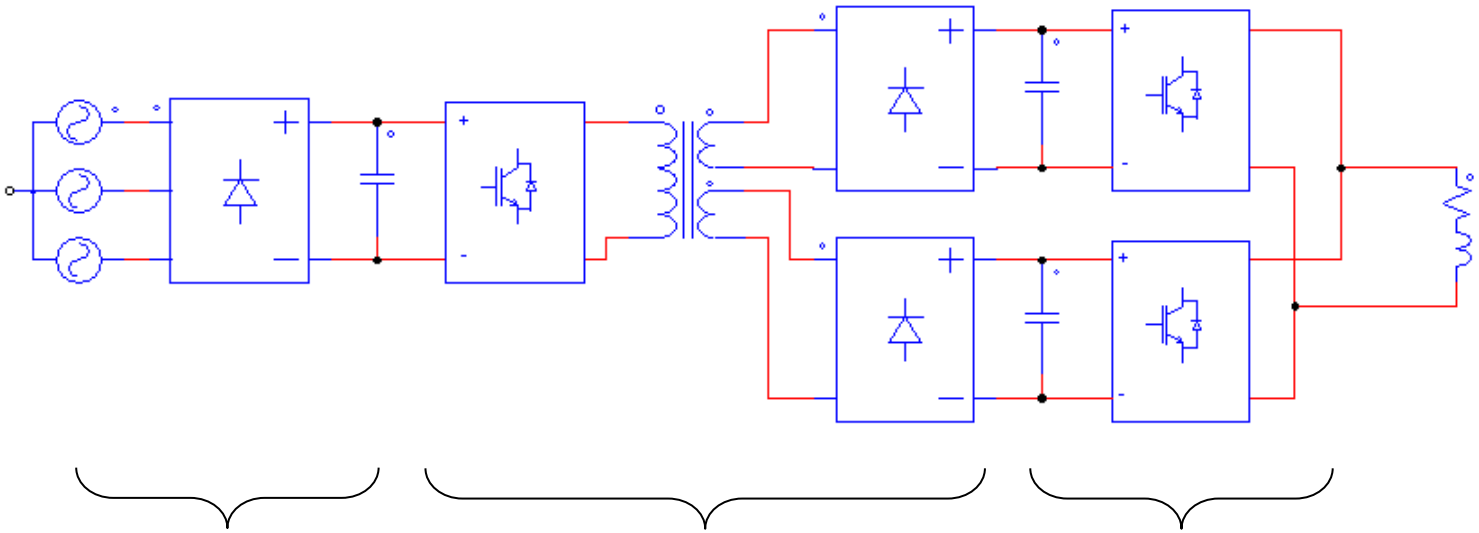
Spare power supply for electromagnetic undulators:

Can be used on different kind of loads when a failure occurs on one of the corresponding power supplies (all from DANFYSIK…)

± 600A / ± 150V ; ± 440A / ± 150V ; ± 360A / ± 250V

Accuracy class: 50ppm

Topology:



Rectification stage

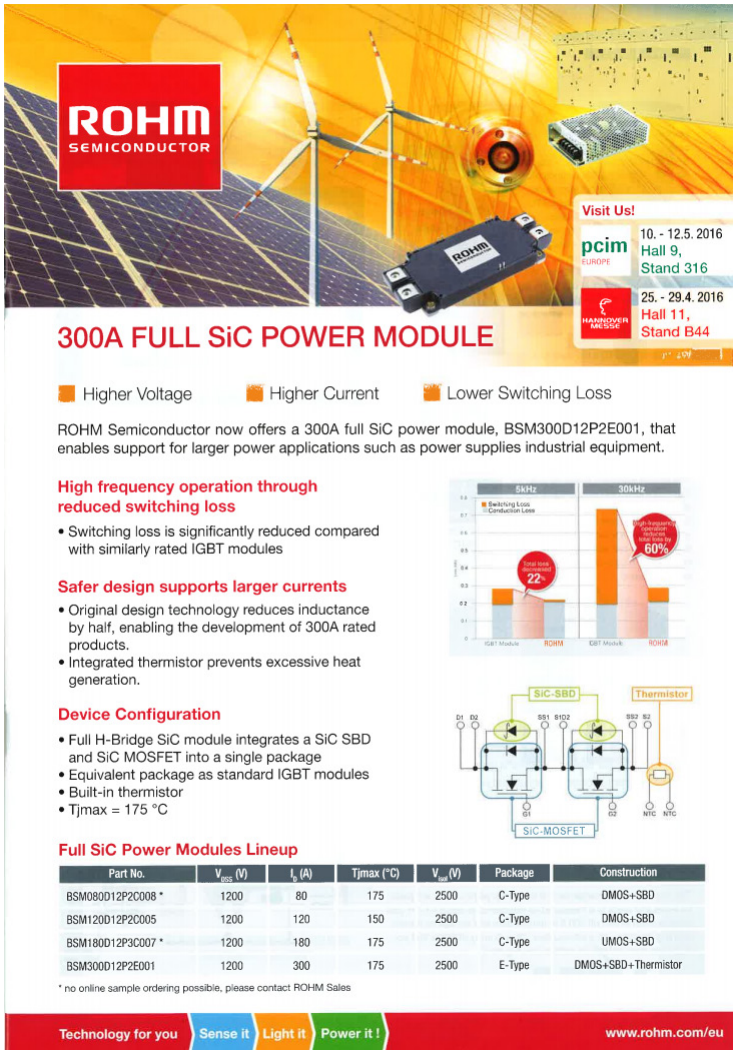
Isolated DC/DC stage
Phase shifted converter
Fsw = 20 kHz

2 interleaved
4Q converters
Fsw = 20 kHz

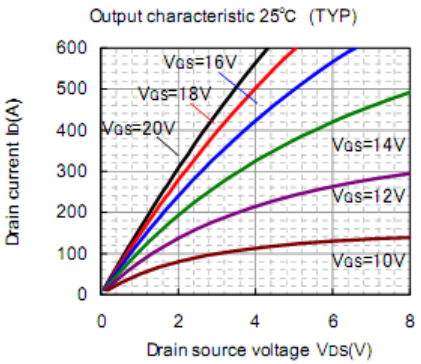
New developments

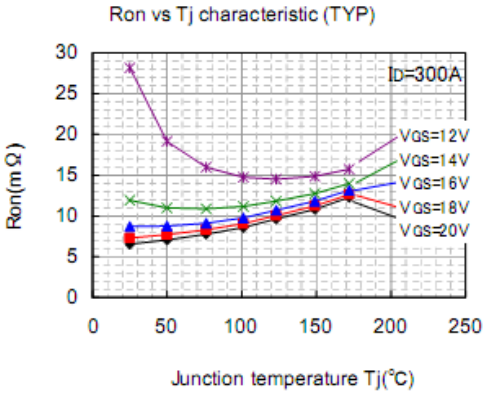
Spare power supply for electromagnetic undulators:

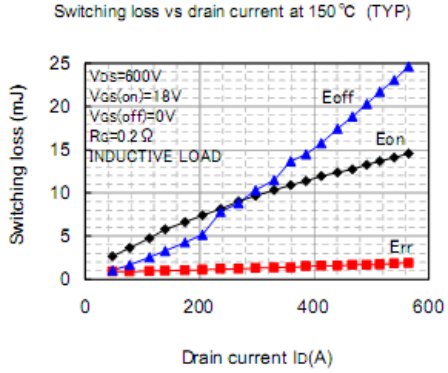
« Bodo's Power » magazine (04/2016)

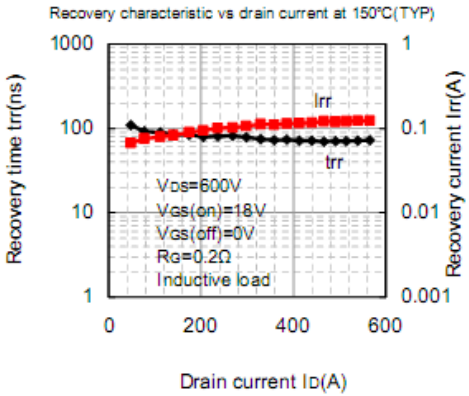


BSM300D12P2E001









New developments

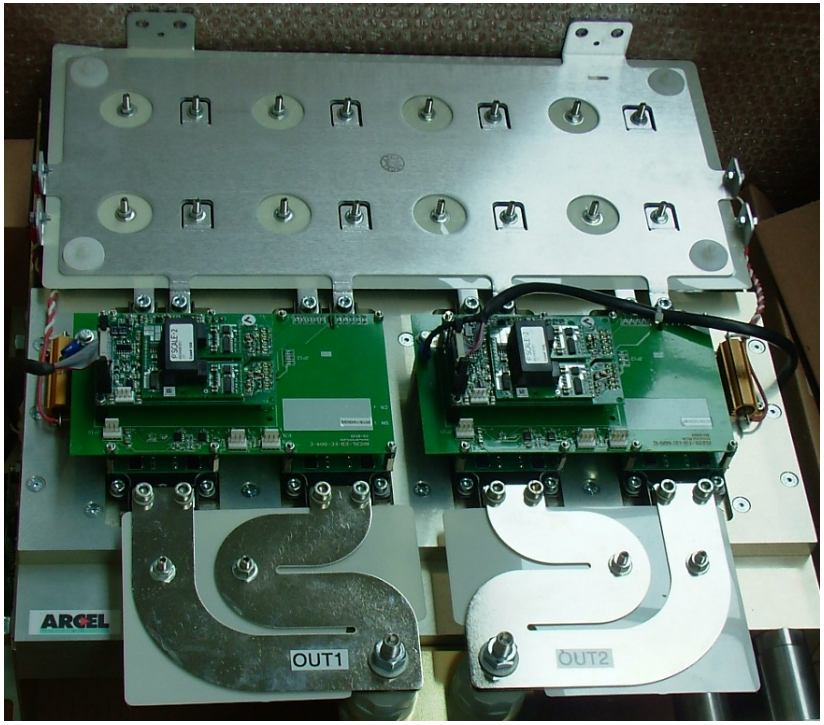
Spare power supply for electromagnetic undulators:

Comparison standard module IGBT+Diode Si vs. module MOSFET+Diode SiC

Module Si FF300R12KT4 INFINEON						
Pcond T	Pcom T	Pcond D	Pcom D	P tot module	Tj T	Tj D
165 W	335 W	65 W	240 W	805 W	128°C	126°C

Module SiC BSM300D12P2E001 ROHM						
Pcond T	Pcom T	Pcond D	Pcom D	P tot module	Tj T	Tj D
240 W	140 W	80 W	30 W	490 W	107°C	89°C

40% reduction in power losses @ 20kHz



Use of Concept drivers with voltage level shifter $\Rightarrow V_{GS}$ = +20V / -5V

Some reflections on the main topic

Performance specification, reviewing and testing

Some reflections on the main topic

SOLEIL construction phase:

- PS specifications not detailed enough, especially in terms of EMC (only a list of standards to comply with…)
- Reviewing: Sizing of main power components (semiconductors, capacitors, etc…) not checked
- Testing: Mainly measurements of output characteristics (current precision + voltage ripple in DM), no thermal / EMC measurements…

⇒ **Serious troubleshooting during first years of operation**

A positive point nonetheless:

Documentation complete (Schematics, BOM, manuals, Gerber files, firmware sources except those from DANFYSIK…)

Some reflections on the main topic

Non exhaustive list of items that should be detailed in a technical specification:

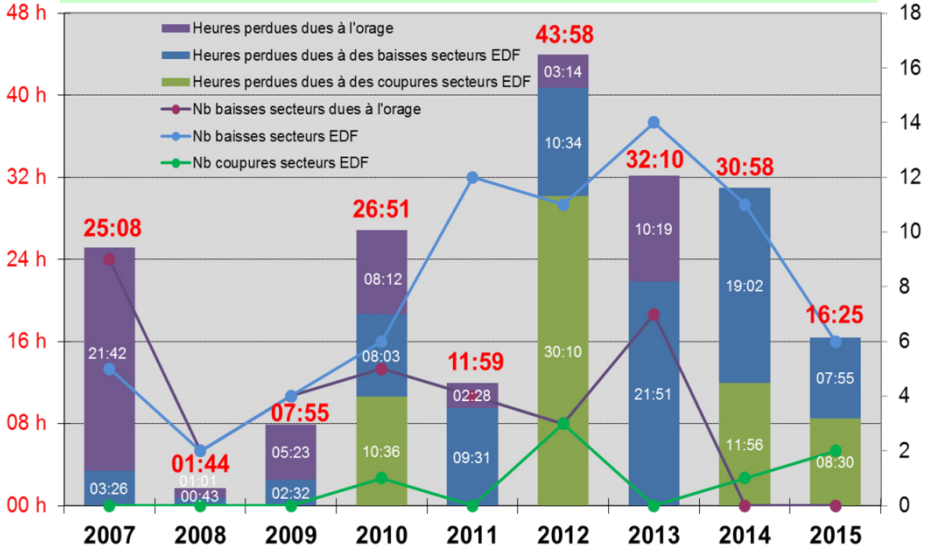
- Power converter ratings
- Load characteristics, magnet cycles, di/dt limits
- Static performance (current precision, ripples)
- Dynamic performance (reference tracking, overshoots, AC line disturbance rejection)
- Synchronisation between PS if required
- Control system
- Internal / external interlocks
- Magnet earthing
- Environment (Electricity, cooling)
- Efficiency, power factor, THD
- Layout, weight / volume
- Contract execution, schedule, progress report, acceptance tests
- Documentation
- Spare parts
- EMC (immunity / emissions)
- Acoustic noise
- Design rules (semiconductors, capacitors, fans…)
- Reparability

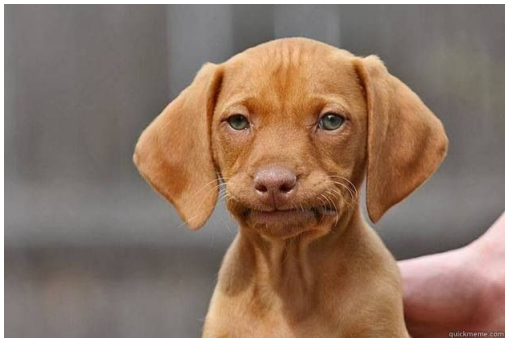
Some reflections on the main topic

- AC line disturbance rejection

Nb. beam losses / hours of beam lost

due to mains voltage drops / losses





Some reflections on the main topic

- AC line disturbance rejection

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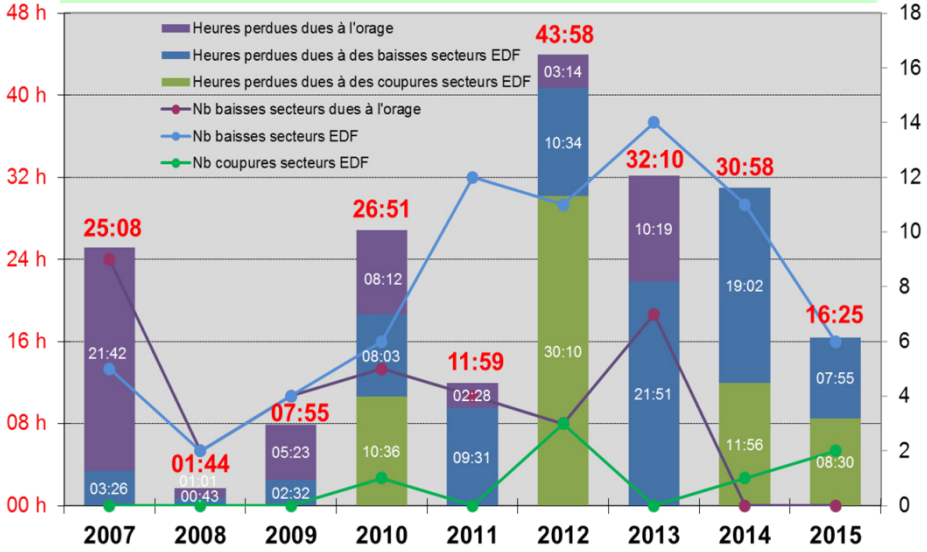
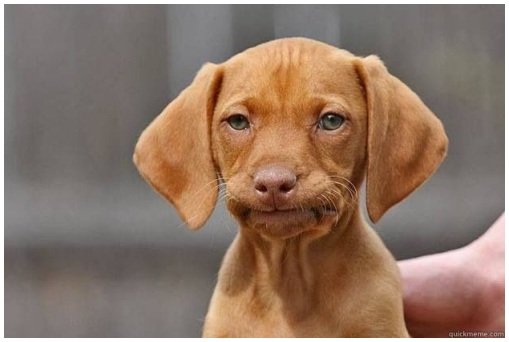
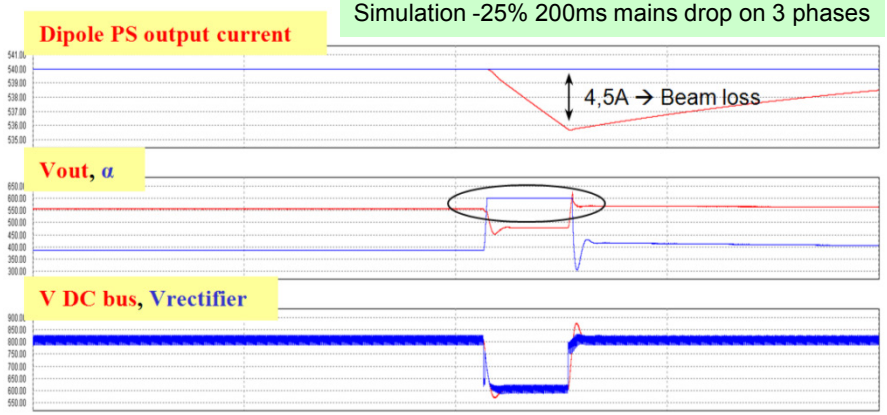




Simulation -25% 200ms mains drop on 3 phases



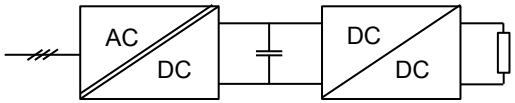
Most events: Voltage dips < 25% on 1 to 3 phases with a duration < 150ms

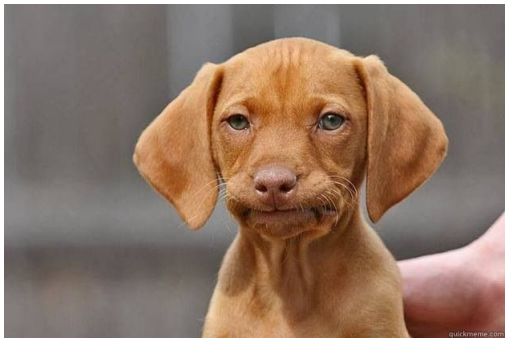
Storage Ring power supplies	Dipole PS 610V/580A	Spare Dipole PS 610V/580A	Spole PS 75V/350A	Spole PS 140V/350A	Qpole PS 14V/250A	Qpole PS 22V/250A
% of DC link voltage drop causing saturation of regulation (for usual current setpoints)	12%	25%	55%	30%	45%	40%

Some reflections on the main topic

- AC line disturbance rejection

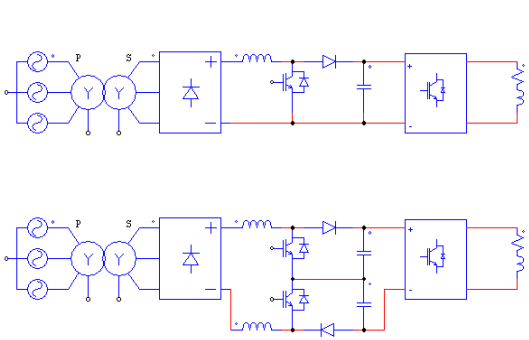
Typical converter topology

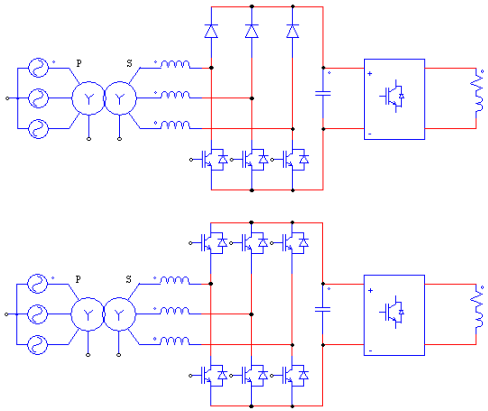


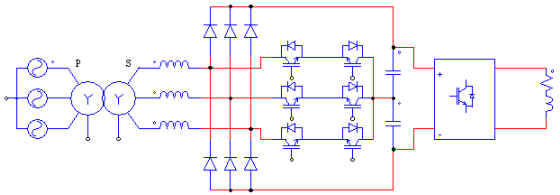


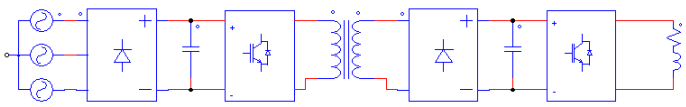
Possible solutions:

- Diode rectification stage delivering high enough DC link voltage to avoid saturation of output stage converter during mains voltage sags
- Controlled AC/DC input stage to regulate DC link voltage at the desired value
  Galvanic isolation: Possibility to introduce a high frequency transformer (weight/volume ↘)
  PFC circuits can be implemented







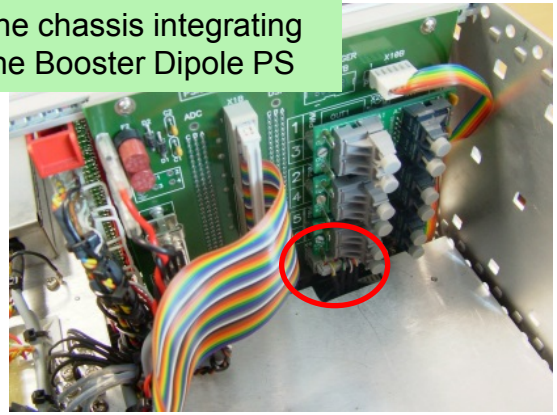


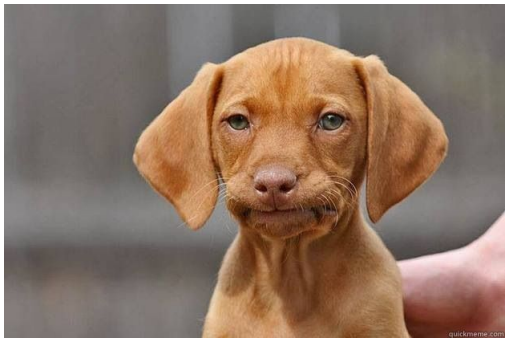
Some reflections on the main topic

- AC line disturbance rejection

- EMC (immunity / emissions)

2007 : Serious EMC pb with the chassis integrating the PSI regulation cards on the Booster Dipole PS



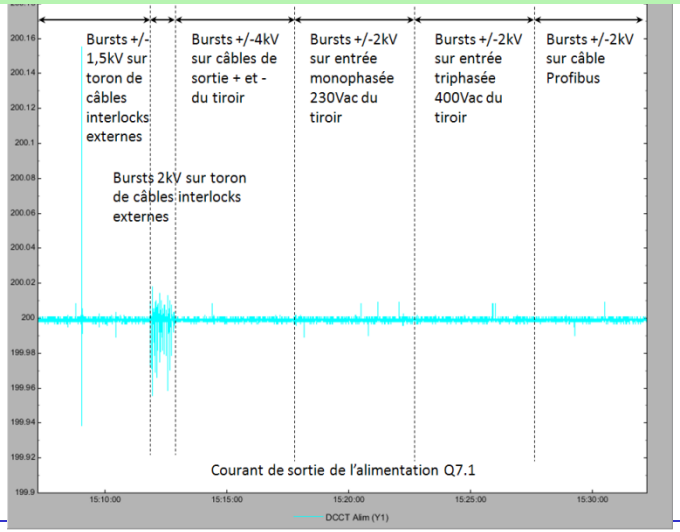


DSP crash in master/slave configuration:

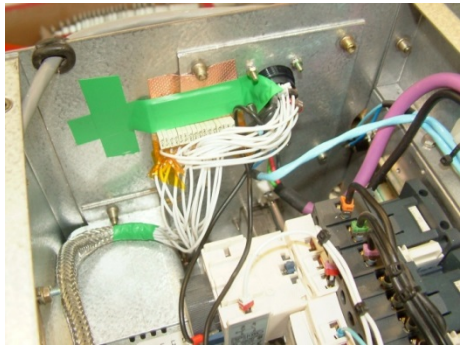
Use of unshielded flat ribbon cable for the serial link between PSI master & slave cards (= transmission line)

The good solution: Common backplane card for master and slave cards with controlled trace impedance

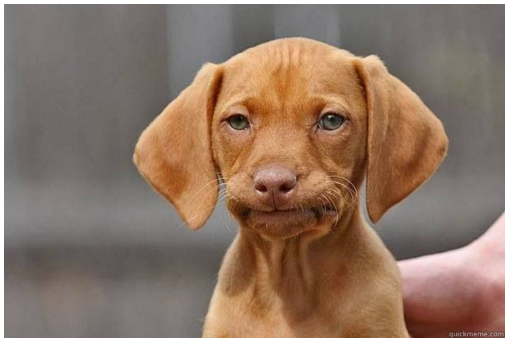
Poor EMC on the SR Quadrupole PS



Fast transient burst immunity test ⇒ CM filtering of external AON I/O



Some reflections on the main topic



- AC line disturbance rejection
- EMC (immunity / emissions)
- Acoustic noise

The switching frequencies of most of our converters are > 20 kHz

Big converters (Storage Ring Dipole PS, Booster Dipole PS…): Around 10 kHz (efficiency)

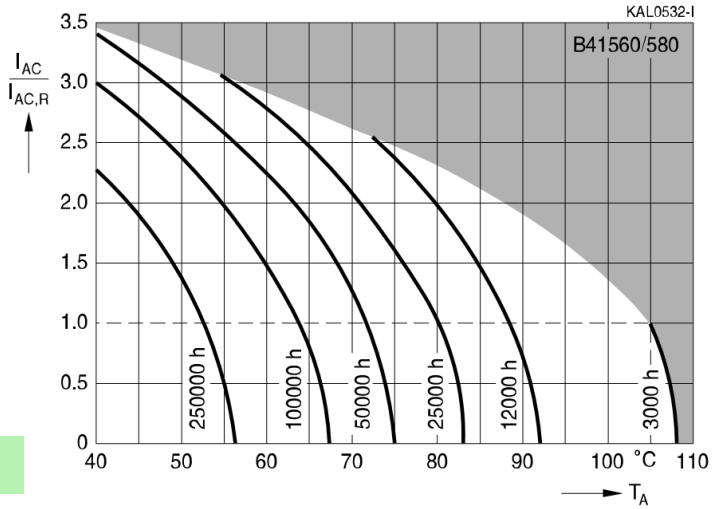
⇒ Acoustic noise!

- Design rules (semiconductors, capacitors, fans…)

Ex: Capacitor lifetime > 100 000 hours in all operating conditions

SR Dipole PS: Redesigned DC link capacitor banks ⇒ 120 000 hours

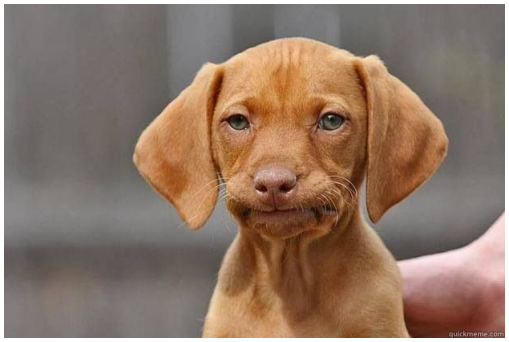
Useful life[1)]
depending on ambient temperature T_A under ripple current operating conditions

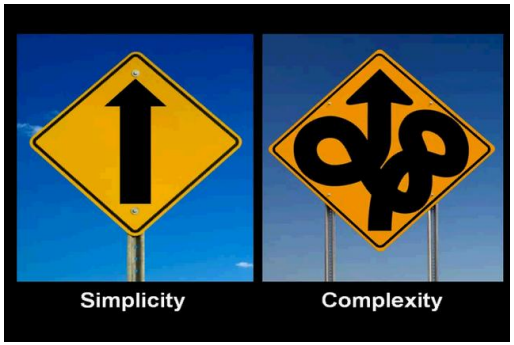


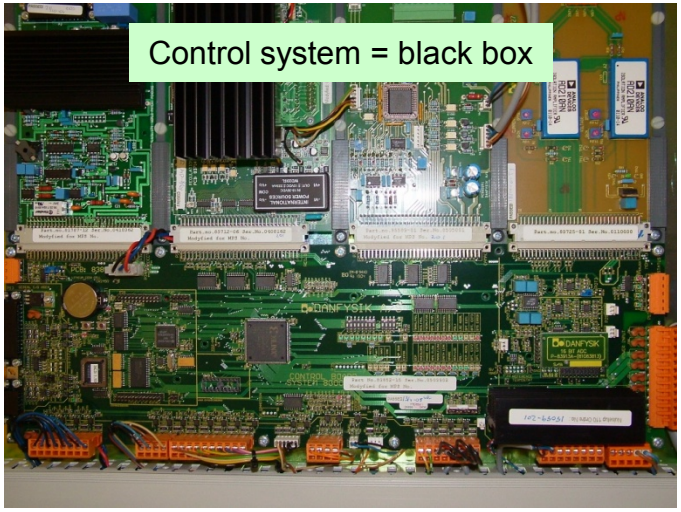
Some reflections on the main topic

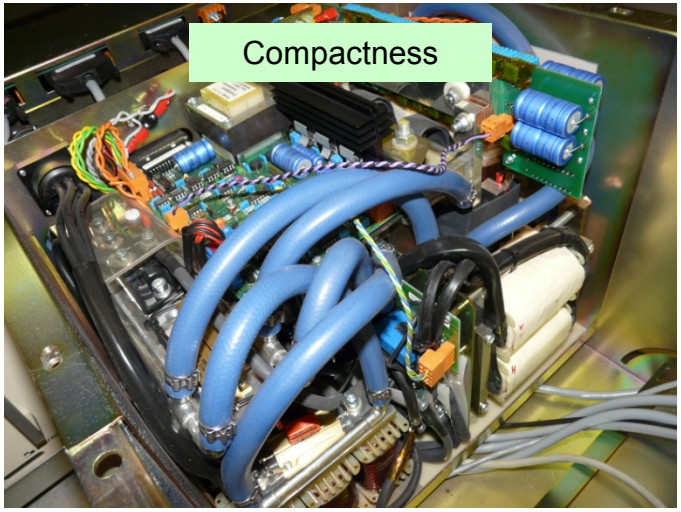
- AC line disturbance rejection
- EMC (immunity / emissions)
- Acoustic noise
- Design rules (semiconductors, capacitors, fans…)
- Reparability

  Unfortunate choice: DANFYSIK power supplies







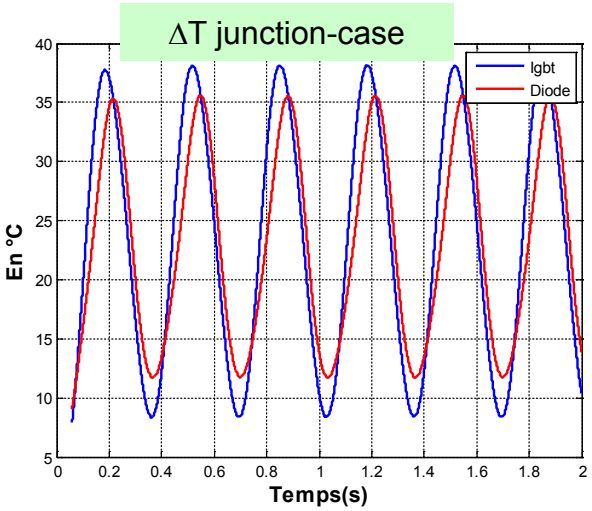


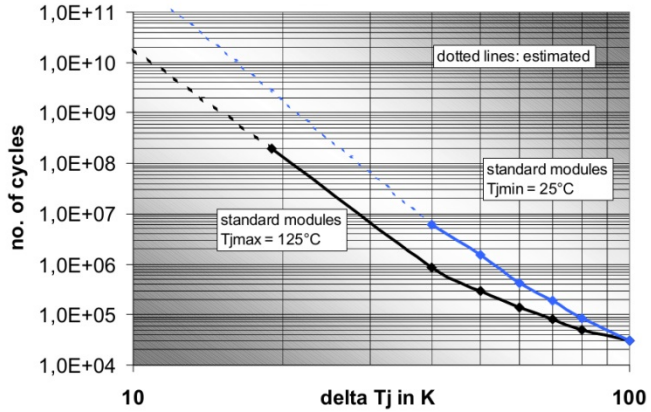
Some reflections on the main topic

Reviewing: Draw upon knowledge and experience of PS experts from other accelerator facilities

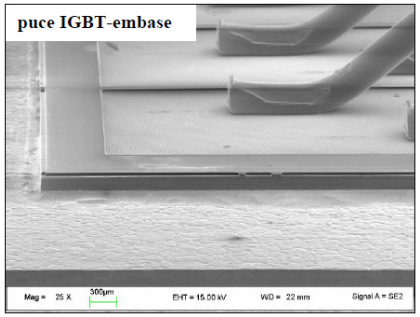
Example: Short lifetime of the IGBT modules in our main 3Hz Booster power supplies

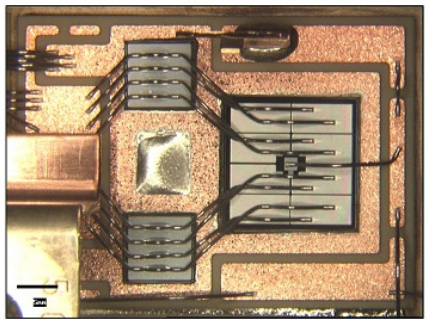
Cause: Harsh power & thermal cycling conditions



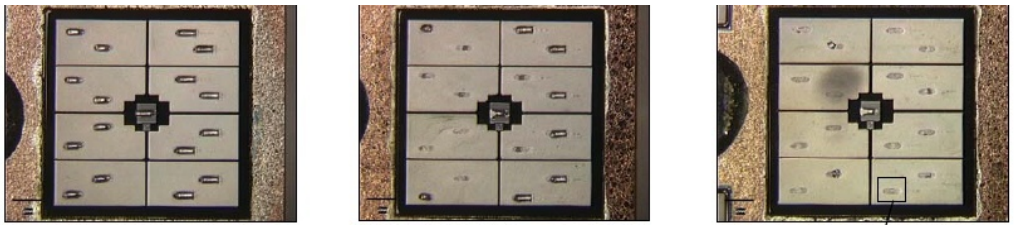


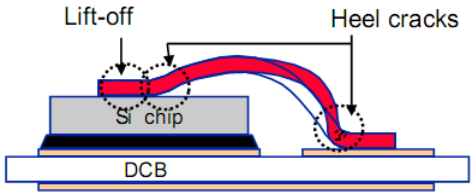
Bonding wire pull test on 3 IGBT modules





Module 1: New	Module 2: 5 Millions cycles	Module 3: 25 Millions cycles
REF (Wedge arraché : 0/64)	(Wedges arrachés : 43/64)	(Wedges arrachés : 60/64)





⇒ **Many failures between 2006 and 2014**

Some reflections on the main topic

Reviewing: Draw upon knowledge and experience of PS experts from other accelerator facilities

Example: Short lifetime of the IGBT modules in our main 3Hz Booster power supplies

Cause: Harsh power & thermal cycling conditions

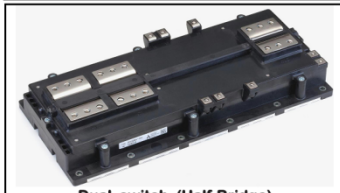
New design in 2014 (~ 120 k€ project, spares included)

MITSUBISHI ELECTRIC

< IGBT MODULES >

CM2500DY-24S

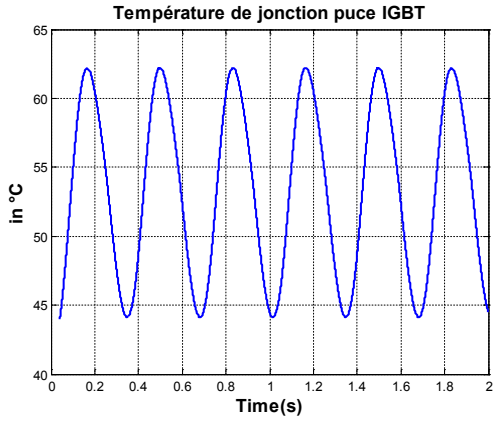
HIGH POWER SWITCHING USE
INSULATED TYPE



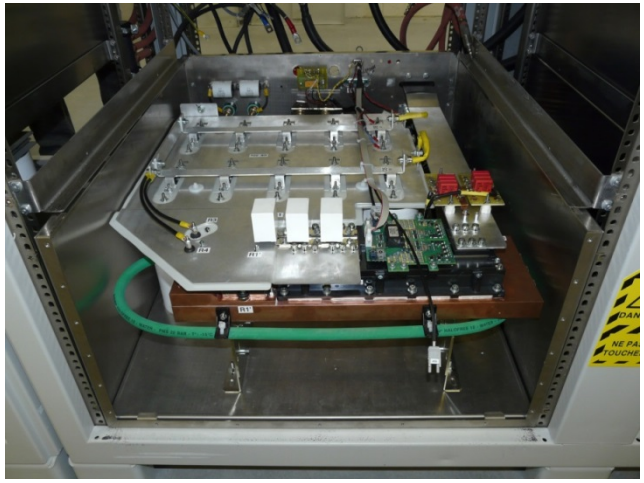
Dual switch (Half-Bridge)

Collector current I_C ..... **2500** A
Collector-emitter voltage V_{CES} ..... **1200** V
Maximum junction temperature T_{jmax} ..... **175** °C

- Flat base Type
- Aluminum base plate
- RoHS Directive compliance
- Recognized under UL1557, File E323585

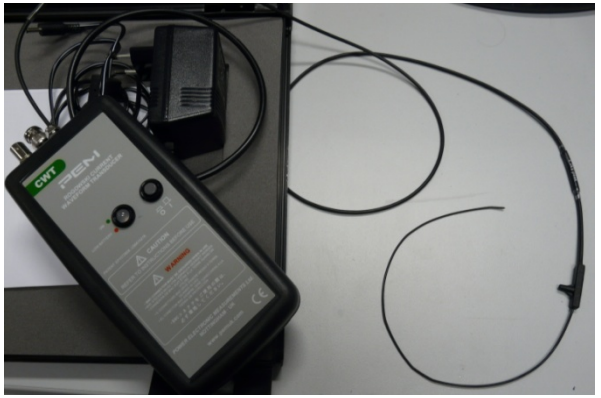


⇒ **IGBT cycling capability > 200 Millions (~ 20 years)**



Some reflections on the main topic

Testing: You need tools (seems obvious and it is)…



Questions

Thank you for your attention.
Questions ?