MAGNET POWER SUPPLIES RELIABILITY IMPROVEMENTS AT SOLEIL

F. Bouvet*, P. ALexandre, R. Ben El Fekih, S. Bobault, M. Bol, Y. Bouanani, Y. Dietrich, E. Dupuy, P. Lebasque, A. Letresor, D. Müller, Synchrotron SOLEIL, FRANCE

* francois.bouvet@synchrotron-soleil.fr

Maintenance and ugrades of the magnet power supplies are a critical consideration for our facility since the injector complex is already 10 years old and main of the Storage Ring equipment are approaching the same age.
This poster first focuses on the main maintenance operations carried out on these systems, which represent more than 600 power converters. Two important reliability improvements implemented on the Booster 3Hz power supplies and on the Storage Ring quadrupole power supplies are then detailed.
Finally, the in-house contruction of new spare power supplies, in order to improve the equipment availability, is presented. The strategy adopted regarding the spare parts for the whole of our equipment is also examined.

Power converter operation: Availability is crucial [A = MTBF/(MTBF+MTTR)]

How to improve MTBF (Mean Time Between Failure) and MTTR (Mean Time To Repair) ?

- **MTBF:**
  - Careful design to get a high MTBF (> 100'000h)
  - Over dimensioning (e.g. junction temperature of semiconductors < 100°C)
  - Systems built as simple as possible
  - Development of remote diagnostic tools to prevent breakdowns (e.g. surveillance of power supplies output ripple)
  - Systematic analysis of any dysfunction (to do so, complete schematics of all the systems + firmware sources are compulsory)
  - Preventive and curative maintenance (taken care of by the Power Supplies and Pulsed Magnets group in most cases ; diligent follow-up of subcontracted operations)
- **MTTR:**
  - Spares, switchable spares
  - Reparability (too complex / compact systems are difficult to repair)
  - Modular design (reuse of modules in different applications)
  - Extensive self diagnostic (allowing quick detection of faulty element)
  - Skilled personnel available on short notice (< 1h at site)
  - Detailed procedures for on-call interventions

Management of obsolescence is also a major concern :

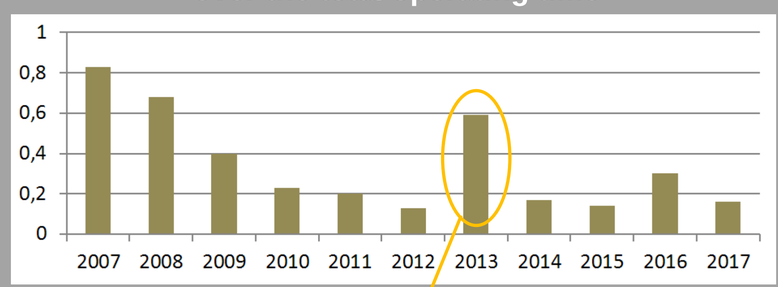
- Identification of critical parts at risk of going obsolete
- Building ad hoc strategies: Buying and storing critical parts / finding non-obsolete substitute parts / localized or complete redesigning

Preventive maintenance:

- **Campaigns conducted annually:**
  - Dust removal, tightening of power connections in the main Storage Ring (dipoles & sextupoles) and Booster (dipoles & quadrupoles) power supplies
  - Checking (and replacement if needed) of the cooling fans
  - Infrared analysis in all the cabinets (to detect loose connections, anomalies)
- **Electrolytic capacitors:**
  - Measure of the capacitor values in the main Storage Ring and Booster power supplies (every 2/3 years)
  - Replacement if necessary
- **Thermal grease between heatsink and IGBT module baseplate** (used to reduce the thermal contact resistance): Re-application after 10 years of operation in the main Storage Ring and Booster power supplies
- **Maintenance campaign on the ~180 Storage Ring quadrupole power supplies (2016/2017):**
  - Dust removal
  - Mechanical changes to improve maintainability and reparability
  - EMC improvements

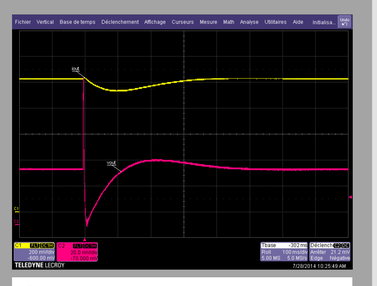
Power supplies reliability improvements

% of user beam unaivalability due to power supplies over the total operating time



70% of the power supply incidents caused by the Storage Ring quadrupole power supplies: Erratic and transient current spikes at converters output, inducing beam losses

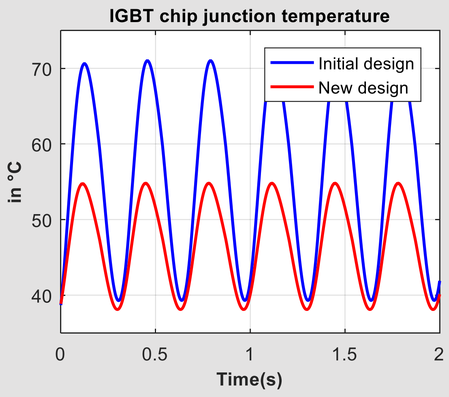
After meticulous investigations, a software bug in the regulation card firmware has been brought to light: For very specific values of the current measure, the microcontroller of the regulation card can retrieve erroneous data, thus perturbating the regulation loop.
All the regulation card (~180) have been reprogrammed with a corrective firmware in mid-2014 by the Power Supply team.



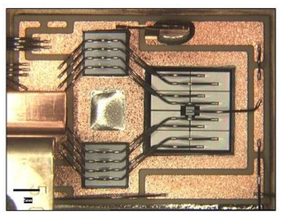
Current (yellow curve) and voltage (red curve) deviations during the dysfunction of a quadrupole power supply

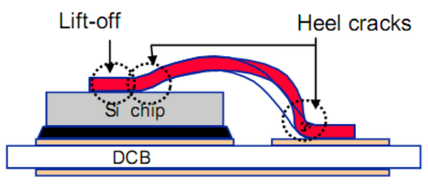
Power racks of the 3Hz Booster power supplies

2005 – 2014: Many failures on the 3Hz Booster power supplies
=> Interruption of the Top-Up operation for at least 2 hours (minimum time for repairing)
Lifetime of the IGBT (Insulated-gate bipolar transistor) modules used in the 4-Q output stage of the Dipole power supplies **< 3 years!**
Cause: High thermal stress generated by the 3Hz excursion of the IGBT chip's junction temperature => Poor power cycling capability (< 25 million 3Hz cycles)



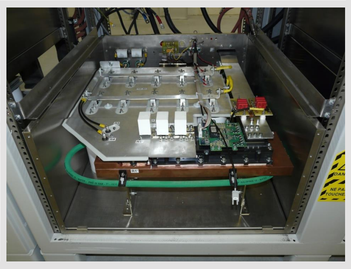
IGBT modules are composed of several layers of different materials with different coefficients of thermal expansion => Shear stresses in case of high temperature swings





2013/2014: In-house redesign of the power racks:

- Based on 1200V / 2500A IGBT modules with high thermal / power cycling capability
- Calculation of IGBT junction temperature excursion: < 20°C
- Estimation of the IGBT cycling capability: > 200 Millions



Spare parts management

Initial spare strategy:

- For low power devices (like quadrupole or corrector power supplies): Complete spare converters (~7% of the total number) + spare parts for repairs
- Only spare modules and spare parts for the bigger systems: Of course, repairing such systems can take a long time depending on the failure complexity (e.g. many hours of beam interruption in October 2008 (48 hours) or November 2009 (24 hours) during repairs of the Storage Ring dipole power supply)

Since 2012: In-house construction of spare power supplies for the bigger converters

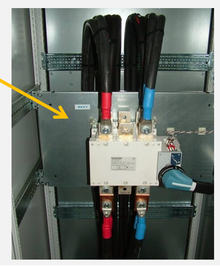
Computerized Maintenance Management System (CMMS):

- All the equipment and their main parts are codified (barcodes) and inventoried in the equipment database, as well as their main spare parts
- Chronological events (incidents, repair interventions, maintenance operations) are recorded for each equipment in the database

Spare Storage Ring dipole power supply (400 kW):

- Switching from the original power supply to the spare one takes less than 15 minutes (can be fulfilled by the machine operator)
- Since its installation, many hours of beam saved (breakdowns of the original dipole power supply occured in 2015 and 2017)

IGBT stack



Changeover switch

On-going developments:

- Spare power supply (50 kW) for the 10 SR sextupole power supplies + the TL2 dipole power supply
- Spare unit (70 kW) for the power supplies of the HU640 undulator

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