Mirko Pojer

WHAT ELSE DID WE LEARN?

Acknowledgements: A. Ballarino, S. Claudet, S. Deleval, R. Denz, V. Montabonnet, Y. Thurel, M. Zerlauth

B. Bellesia, R. Schmidt, M. Solfaroli, A. Vergara

CERN

PREAMBLE

Which was the objective of Hardware Commissioning?

- ✓ Defining the commissioning programme to qualify magnets and equipments (sequences of test steps) after the individual system tests
- ✓ Ensure that all conditions required to start the tests are met
- ✓ Find non-conformities before they become critical for the operation
- ✓ Prepare the superconducting circuits for the exploitation of the machine
- ✓ Do it efficiently and quickly

Did we get the objective?

Some more hints on how we did (tried to do…) it
and which are the lessons learnt.

OUTLINE

- THE TOOLS
  - Sequencer
  - Post-Mortem browser
  - PIC supervision
  - QPS supervision
  - P2N
  - Databases
- SOME HARDWARE
  - Power Converters
    - LHC 600 A-10V
    - 0V crossing distortion
    - Crowbar issue
  - TS/CV: filters and “Elettas”
  - Cable connections
- CONCLUSIONS

THE TOOLS

Efficiency and automation

Mirko Pojer – BE/OP/LHC

POWERING PROCEDURES

- We have been developing detailed procedure for the test of the superconducting circuits and we have as well learnt how to **shorten** these procedures to deal with a tight calendar, without any compromise with personnel and equipment safety

- We will have now to go a step back, since we have recently realized that the procedures have to be extended to cope with **new verifications and new systems validation** (high current circuits mainly):
  - Calorimetric measurements (is it needed for sectors not yet checked and do we need to repeat measurements on the others?)
  - QPS snapshot for splice investigation
  - Validation of the n-QPS and QDS systems
  - Change of current levels for commissioning (according to the outcome on commissioning energy for this year, but also to the conclusions of the Safety Task-force on access with current)
  - According to a sector history
  - In agreement with change in commissioning parameters through ECRs
  - . . .

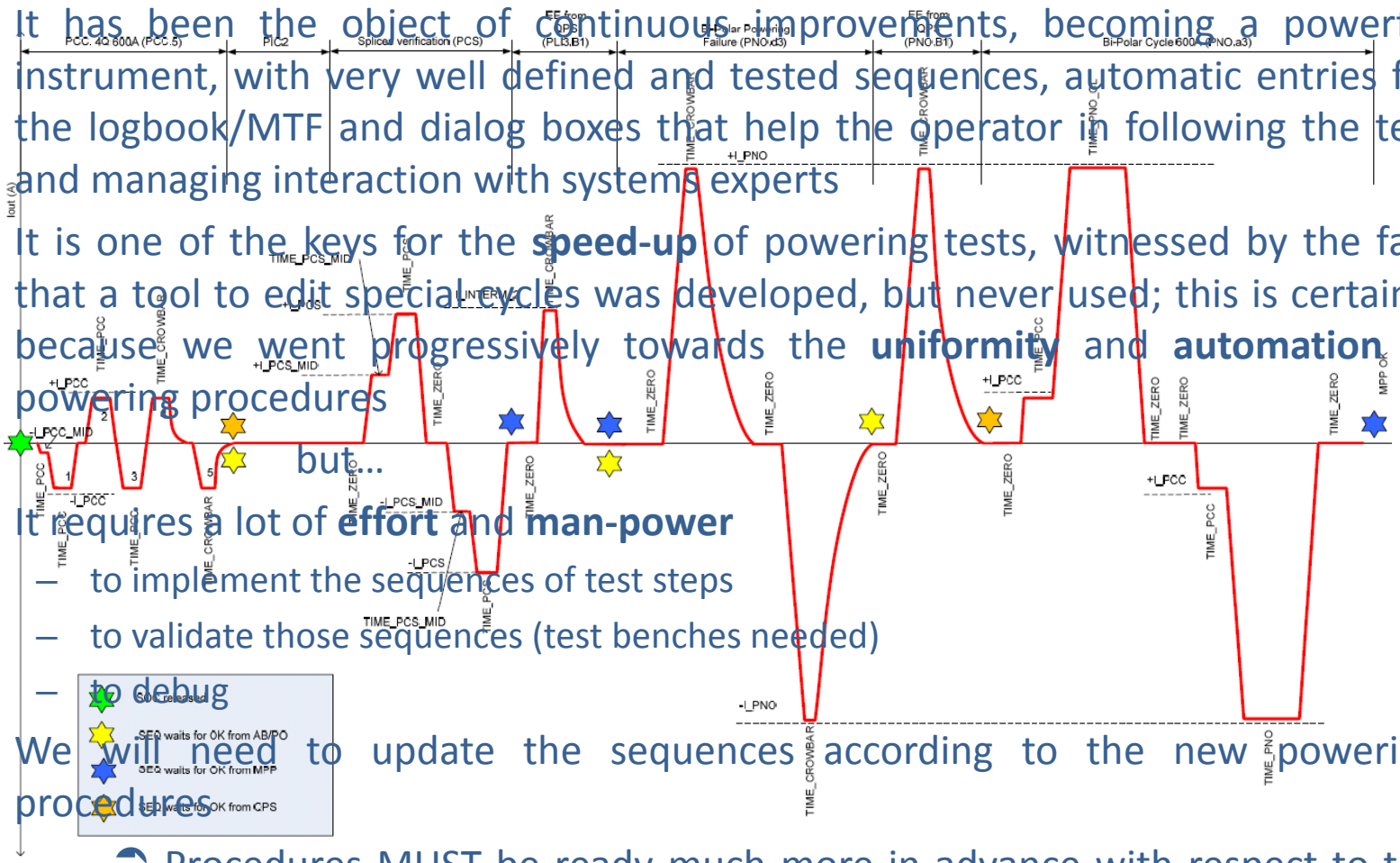
THE TOOLS: SEQUENCER

Sequences = series of test steps defined in the procedures

- It has been the object of continuous improvements, becoming a powerful instrument, with very well defined and tested sequences, automatic entries for the logbook/MTF and dialog boxes that help the operator in following the test and managing interaction with systems experts
- It is one of the keys for the **speed-up** of powering tests, witnessed by the fact that a tool to edit special cycles was developed, but never used; this is certainly because we went progressively towards the **uniformity** and **automation** of powering procedures

but…

- It requires a lot of **effort** and **man-power**
  - to implement the sequences of test steps
  - to validate those sequences (test benches needed)
  - to debug
- We will need to update the sequences according to the new powering procedures

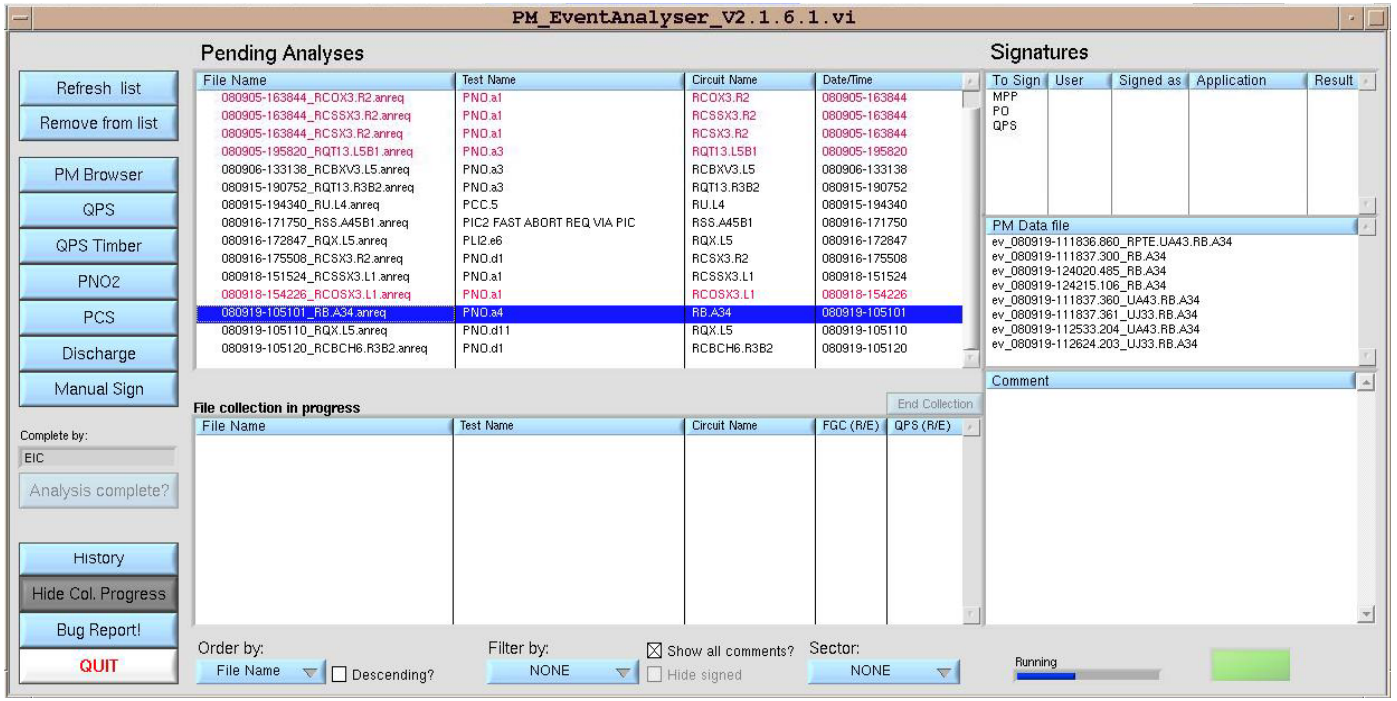


➲ Procedures MUST be ready much more in advance with respect to the beginning of the re-commissioning campaign

Procedures must be ready by end of March at the latest

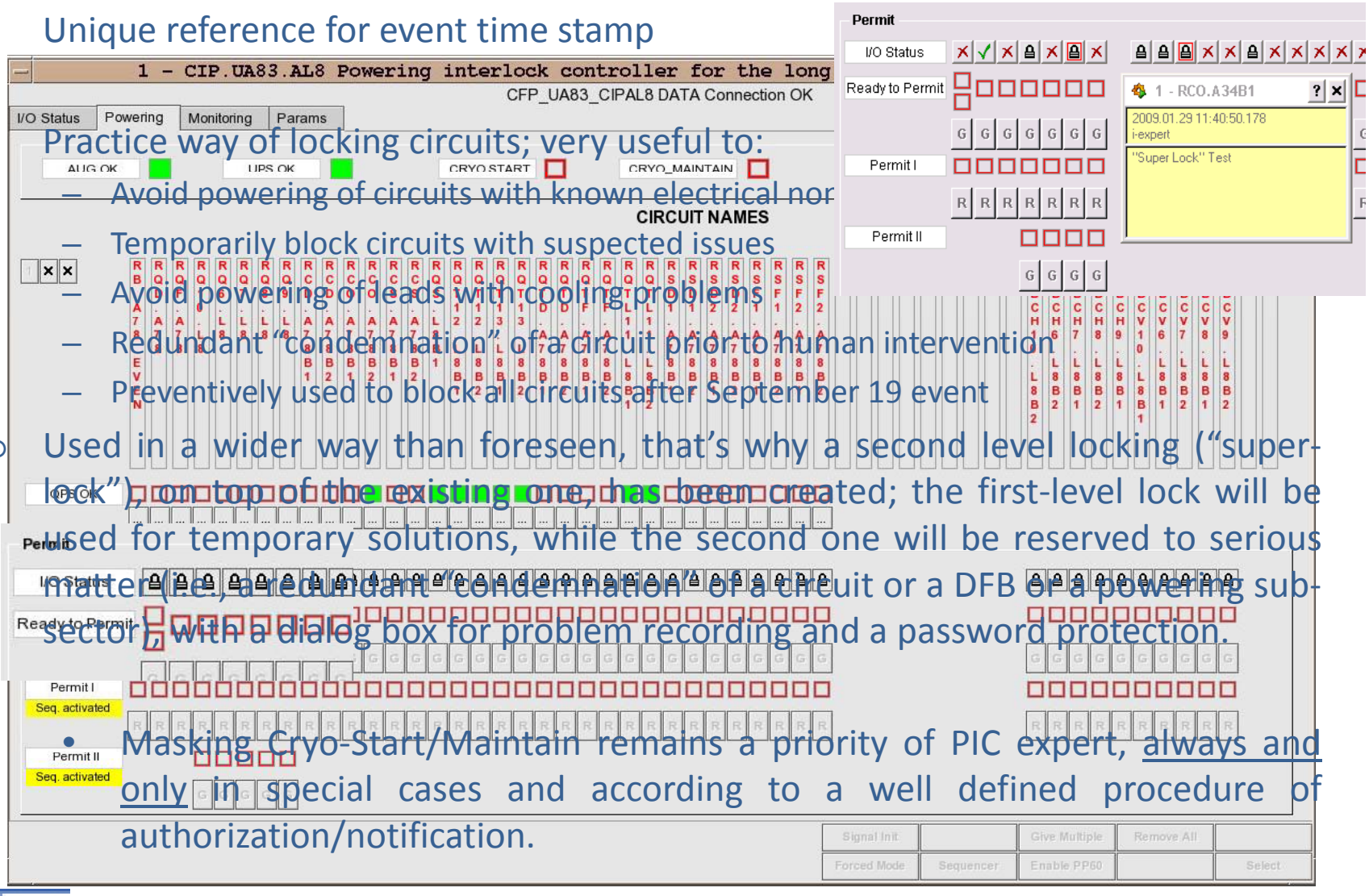
TOOLS: POST-MORTEM BROWSER

- PM tools have enormously increased test **efficiency**
- The PM_Event_Analyser interface helps the experts to better follow test execution, to retrieve data for analysis and to stop continuation of tests in case of non-conformities; the EIC can better interact with experts, prioritizing request of signature
- PIC test analysis and approval will be fully automated for the re-commissioning, apart for the 13-kA circuits
- What could be improved is an automatic reporting/notification to system engineer to follow up non-conformities



TOOLS: PIC SUPERVISION

- Unique reference for event time stamp
- Practice way of locking circuits; very useful to:
  - Avoid powering of circuits with known electrical nor
  - Temporarily block circuits with suspected issues
  - Avoid powering of leads with cooling problems
  - Redundant "condemnation" of a circuit prior to human intervention
  - Preventively used to block all circuits after September 19 event
- Used in a wider way than foreseen, that's why a second level locking ("super-lock"), on top of the existing one, has been created; the first-level lock will be used for temporary solutions, while the second one will be reserved to serious matter (i.e., a redundant "condemnation" of a circuit or a DFB or a powering sub-sector), with a dialog box for problem recording and a password protection.
- Masking Cryo-Start/Maintain remains a priority of PIC expert, always and only in special cases and according to a well defined procedure of authorization/notification.



- Access-powering link: the need for such a tool has been often emphasized and discussions are on-going

see ***R. Schmidt, "Safety organization" – Session 02***

TOOLS: QPS SUPERVISION

- A lot has to be done… See ***R. Denz, "QPS Upgrade and Re-commissioning" - Session 04***

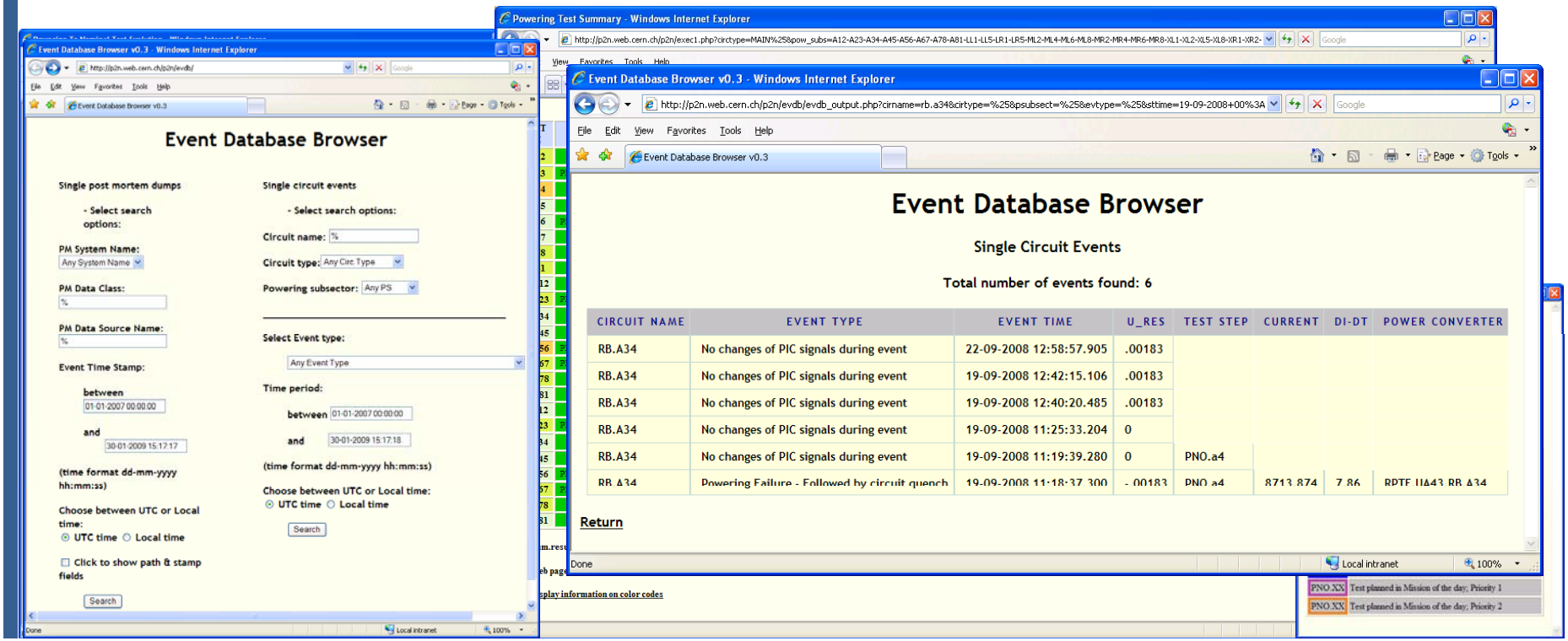
- Software for the n-QPS and QDS
- QPS snapshot software: *Zinur tool* was working fine, but an automatic tool is needed
- Replace all manual resets of QPS controllers with remote power-cycles (new units to be installed)
- Automatic script to close switches was already used during the Machine Check-out and will be extensively used this year, but not before circuit commissioning
- *RBAC* will be implemented in the supervision layer

- The interaction with QPS interface and supervision could be spread among the operation team

- Timing synchronization will be better improved
- Communication problems were sometimes 'annoying' us, but they have been apparently sorted out See also ***E. Hatziangeli, "Controls & software" - Session 07***

TOOLS: P2N

- Powering to nominal web tool (http://cern.ch/p2n), alias Alvaro page:
  - to assist and follow all aspects of the commissioning of the superconducting circuits
    - status of test execution
    - status of commissioning of the superconducting circuits of each sector
    - date and other relevant test information, as reason for test failure
  - to track circuit non-conformities
  - to visualize circuit parameters
  - to define the mission of the day (to be possibly replaced by the electronic logbook)
- Event database browser (http://p2n.web.cern.ch/p2n/evdb/)

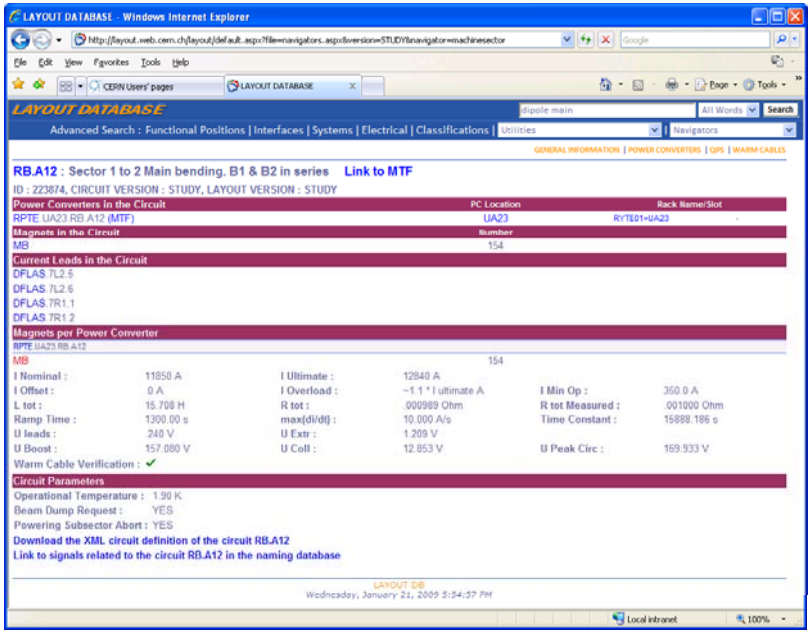


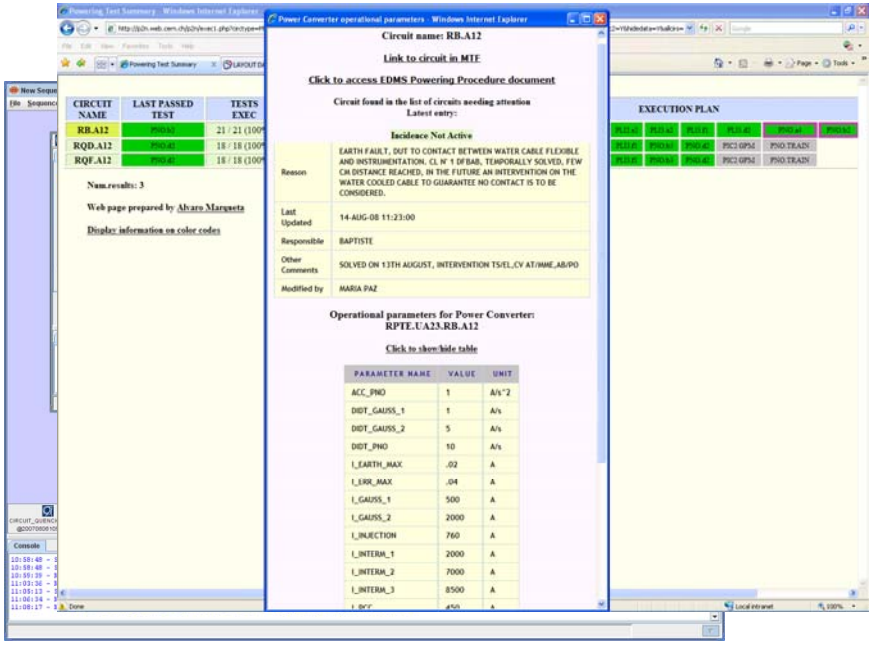
WHAT DO WE NEED MORE?

- A database mechanism to track parameters change (di/dt, acceleration, etc.), possibly in the form of a 'history' of LSA values.
- Calorimetry: is it needed for sectors not yet checked and do we need to repeat measurements on the others? If yes, may we have automatic tools?
- New test campaign: can MTF do the job?

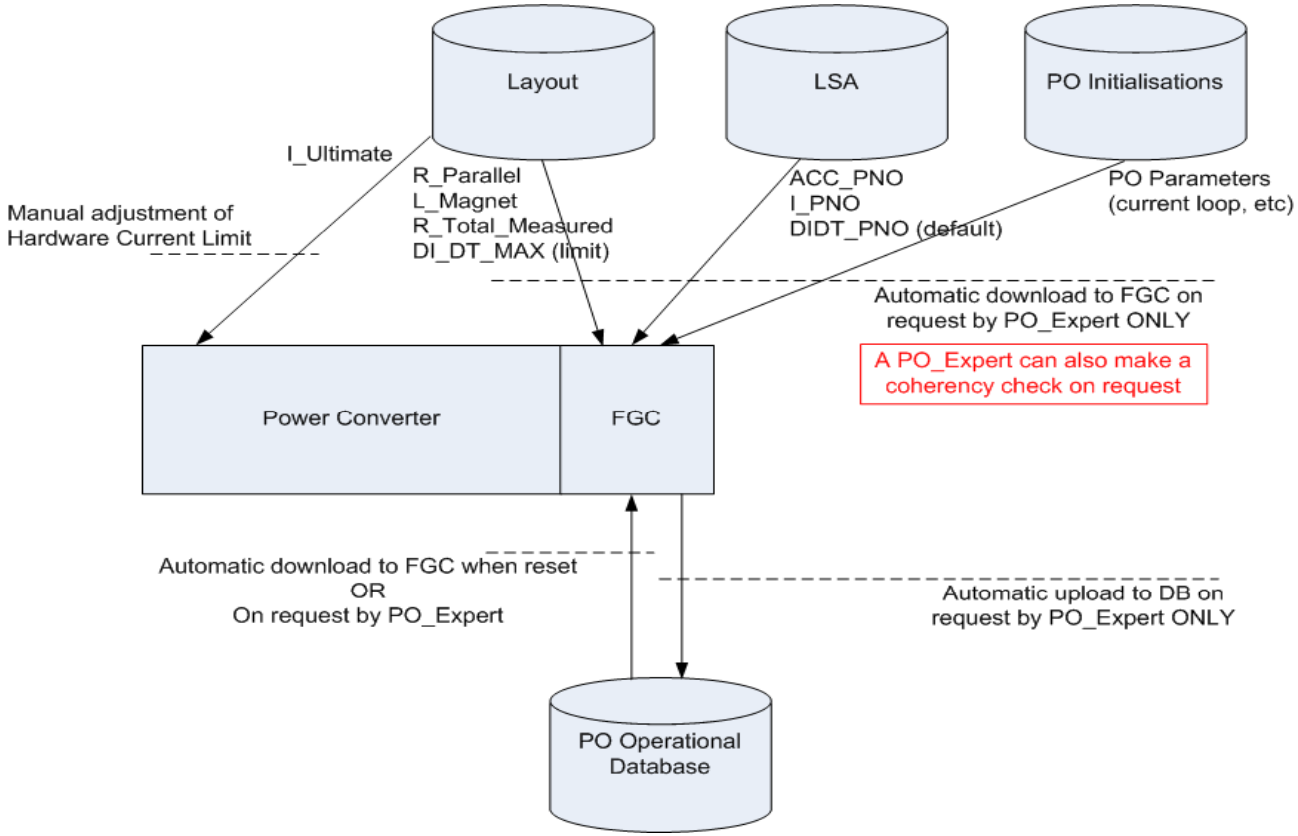
DATABASES

- LHC Layout DB
  - DB holding the design values of the machine, including Layouts, electrical circuits, LHC Equipment Catalogue (e.g. parameters for power converter and magnet types)
  - Rather static data with strict version management (releases + release notes, changes to be documented in an ECR)
- LSA DB
  - Operations database, used for equipment control, settings, etc. during Hardware Commissioning and machine operation
  - LSA offers the required flexibility to adapt to changes of parameters if needed





A THIRD DB



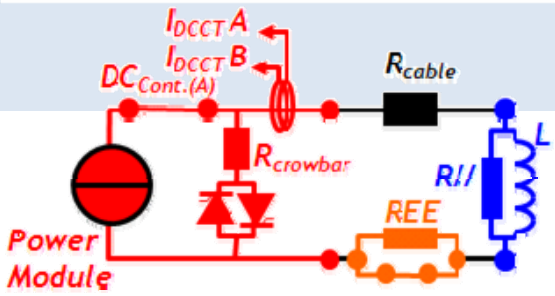
- Parameters are changed in LSA, when necessary and with the agreement of MPP
  - To consistently distribute LSA changes, after every change a PO expert must be consulted to synchronise the FGC and eventually the PO operational DB
  - Frequent changes might however lead to temporary inconsistencies

May we ask to the sequencer to do the synchronization at the beginning of the test? Or take LSA values as the reference? At least for some circuit categories…

SOME HARDWARE

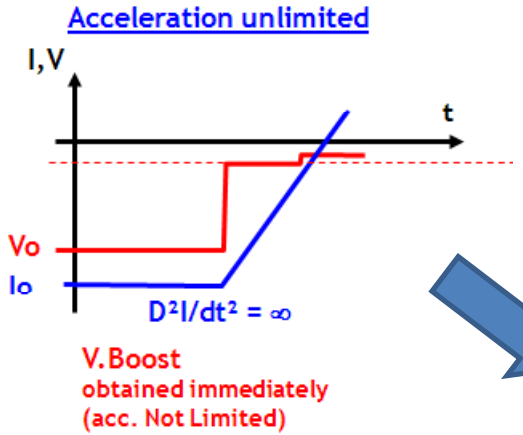
"Puzzling and annoying"

POWER CONVERTERS: LHC 600A-10V

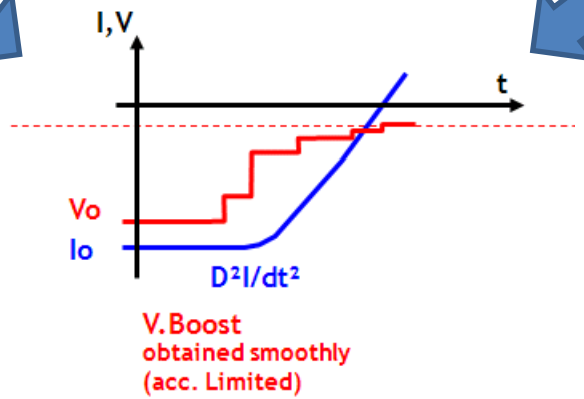


For simplification R//=∞: $\frac{dI}{dt} = \frac{V_L}{L} = \frac{V_{converter} - RI}{L}$

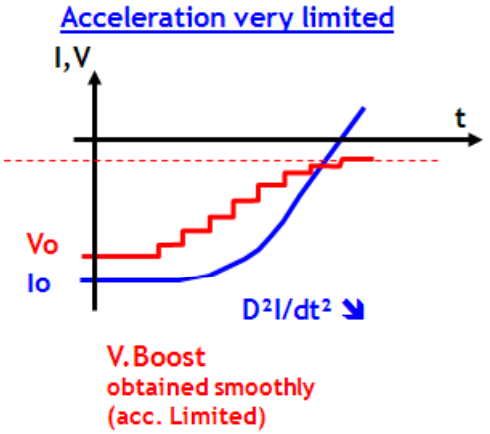
"Physics requirement"



"Compromise"



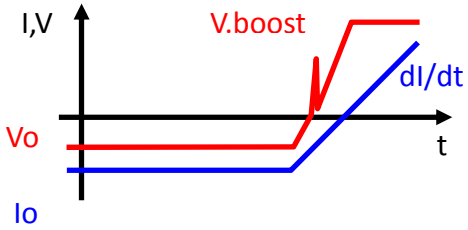
"QPS requirement"



To deduce the resistive component of the magnet load, the di/dt must be calculated by QPS. The use of a derivative in the calculation requires for a long integration time, which is incompatible with reference jumps. Thus the calculation is only accurate for low di/dt and d^2i/dt^2.

LHC 600A-10V: 0V-CROSSING DISTORTION

- The power converters generate some distortion when crossing through zero voltage with current in the load. This is very specific from the 4-quadrant power converter, with the result of a voltage spike (not filterable at the converter level)



Which circuits are more affected and when?
It depends on *R, L, di/dt* and QPS system
--> Circuit-to-circuit analysis!

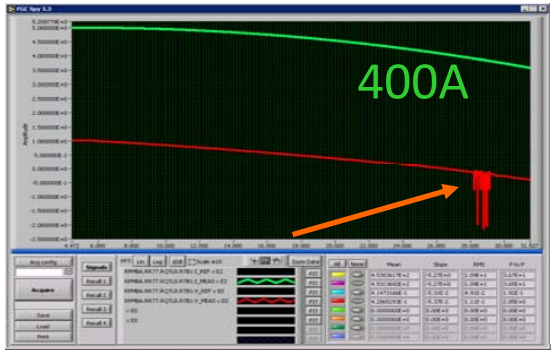
✓ PO made several measurements to characterize the zero-voltage-crossing distortion (distortion is higher at high current)

✓ the QPS team has worked with PO to developed a filter to reduce the effect of the distortion on the voltage measurement (based on image processing techniques)

➲ the solution also improved QPS robustness to di/dt and d^2i/dt^2 parameters

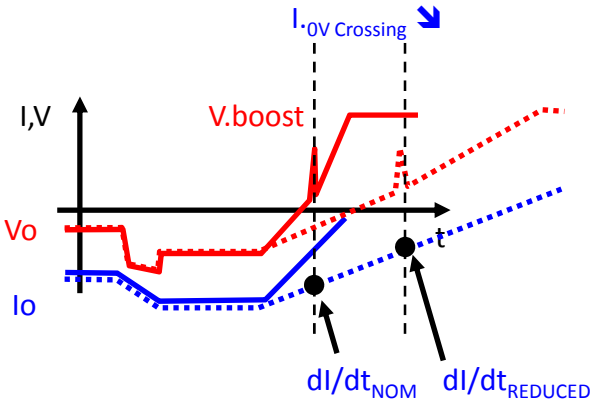
Before:

After:

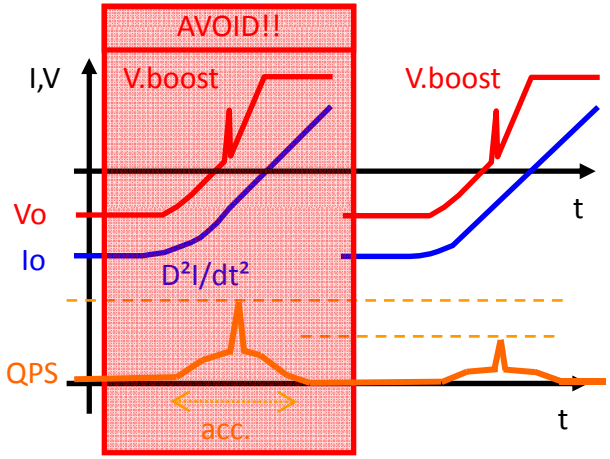


OV-CROSSING DISTORTION *cont.*

- di/dt ↘
  - 0 V distortion occurs at lower current
  - 0 V distortion signal is less important



- d^2i/dt^2 ↘
  - Background noise is lower
  - QPS budget for 0 V distortion is higher

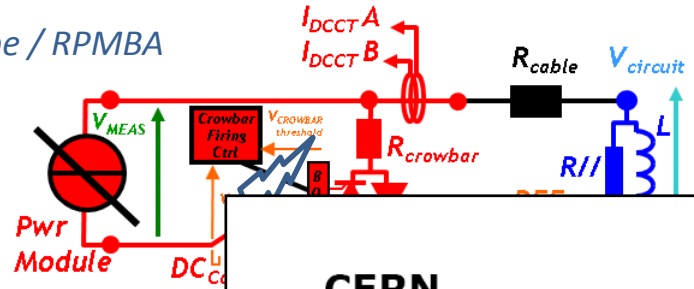


- For a smooth commissioning and operation we need a trade-off between 'required' and 'allowable' parameters value (such a compromise has already lead to a change in parameters during circuits commissioning in agreement with colleagues from ABP)

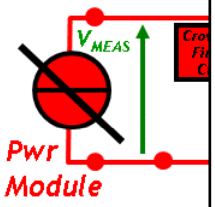
It may go to the detriment of operation and physics

600 A-10 V CROWBAR ISSUE

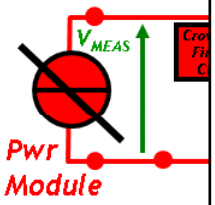
A-Type / RPMBA



B-Type / RPMBB

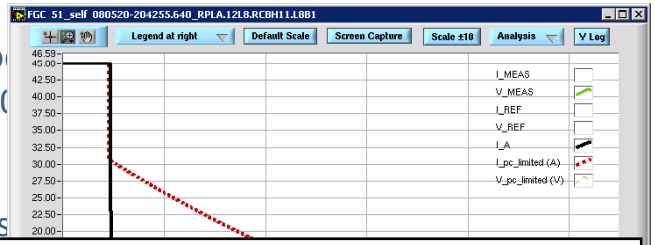


B-Type / RPMBB – no



A 600 A power mo
the range [-20A..2
STILL operating.

The A-Type rack is



CERN
CH-1211 Geneva 23
Switzerland

the **Large Hadron Collider** project

LHC Project Document No.
LHC-RPMB-EC-0001 ver.1.0

EDMS Document No.
977059

Engineering Change requested by (Name & Div./Grp.) :
AB

Date: 2009-01-12

Engineering Change Order – Class II

Brief description of the proposed change(s) :

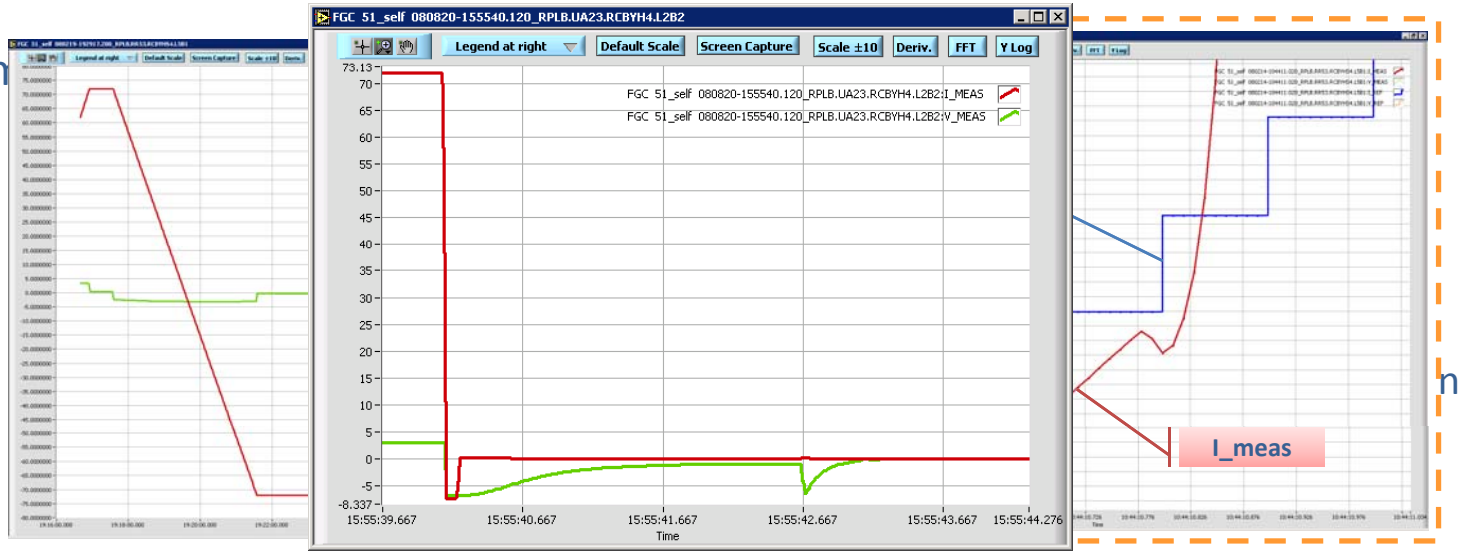
The RPMBB type LHC power converters are not provided with a DC contactor between the power module and the crowbar system. Sixteen circuits in the machine arcs are powered by RPMBB converters without external energy extraction systems. If a quench occurs in one of these circuits and the converter fails with a short-circuit at the level of the output module the discharge time constant will not be determined by the crowbar resistance but by the low resistance of the DC cable, which could be too long for the part being quenched resulting in a damage of the superconductor.

The DC contactor has to be implemented on the sixteen power converters before the end of the 2008-2009 LHC shutdown.

Equipment concerned :	***Drawings concerned :***	***Documents concerned :***
LHC power converters of RPMBB type		**LHC Layout Database** **LHC Integration Documents** **Cablotheque**

120 A Weak Magnets

- Son
  - –
  - –
  - ✓
  - ✓
  - ✓



nsfer

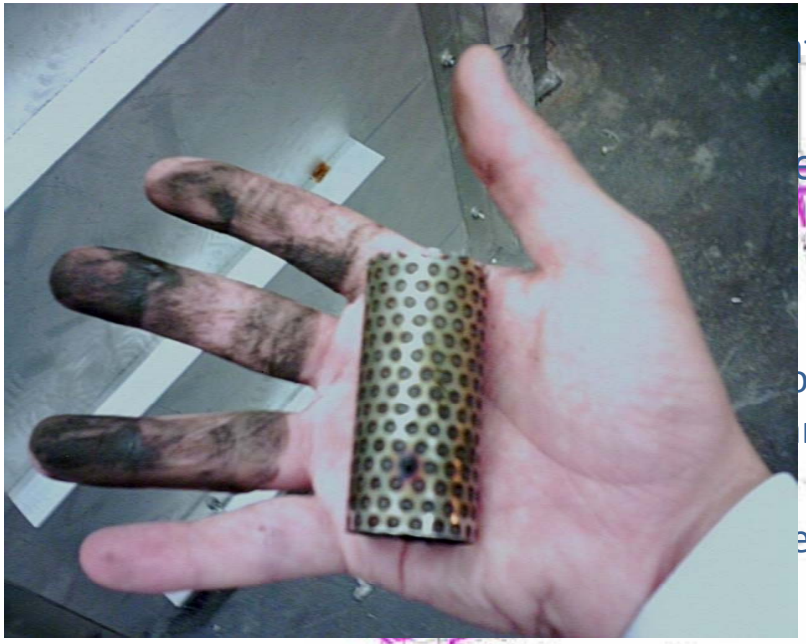
Electrical circuit	Fault	Critical ramp rate
RPLB.RR53.RCBYHS4.L5B1	Cannot handle LHC di/dt	0.6 A/s (LHC: 0.66A/s)
RPLB.UA87.RCBYHS5.R8B1	Cannot handle LHC di/dt	0.46 A/s (LHC: 0.66A/s)
RPLB.UA87.RCBYH4.R8B1	Cannot handle LHC di/dt	0.6 A/s (LHC: 0.66A/s)
RPLB.UJ83.RCBCH7.L8B1	Quench @ discharge	> 2.5 A/s (LHC: 1A/s)
RPLB.UA23.RCBYH4.L2B2	Quench @ discharge	> 1.25 A/s (LHC: 0.66A/s)
RPLB.RR13.RCBCV8.L1B2	Quench @ discharge	1.2 A/s (LHC: 1A/s)
RPLB.UJ23.RCBCV7.L2B2	Quench @ discharge	> 2.5A/s (LHC: 1A/s)
RPLB.UA43.RCBYV5.L4B2	Cannot reach nominal current	

Rated 72 A, it cannot go higher than 65 A

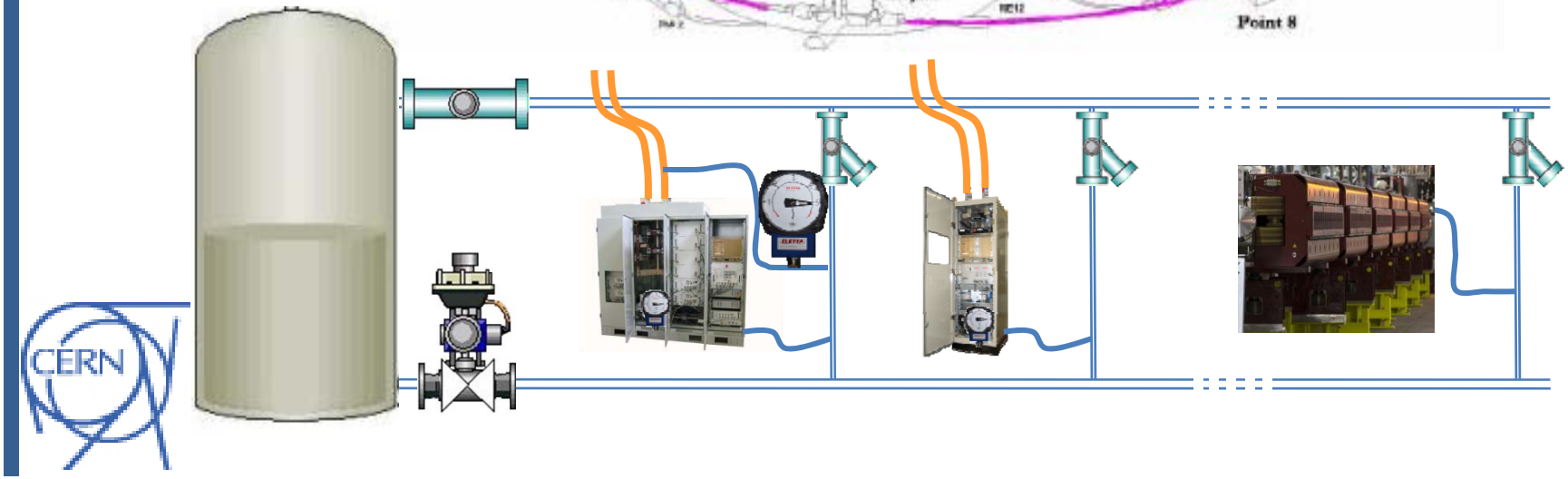
There are many other problems identified and solved by PO….

…. but this does not want and cannot be an exhaustive list !

TS/CV: FILTERS AND "ELETTAS"

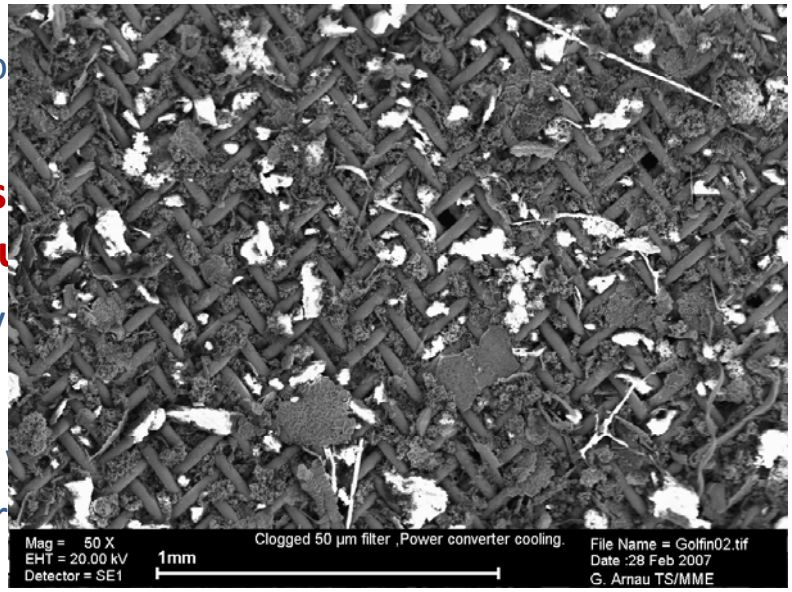


Observation: frequent clogging of the filters with flow reduction and triggering of the Eletta ➲ converter in FPA



FILTERS AND "ELETTAS" *cont.*

- Filt d systematically cleaned before any long powering per Check-out were several times stopped because of this ere treated 3-4 times)
- Sor ns:
  - ob, blocking impurities that would possibly deposit inside
  - s performed on the samples and showed high content of es (opening of the circuit for cleaning could contribute to umulation)
  - ess often repo



➲ **A decision was taken to change all filters 50 µm to 100 µm mesh (already successfu**

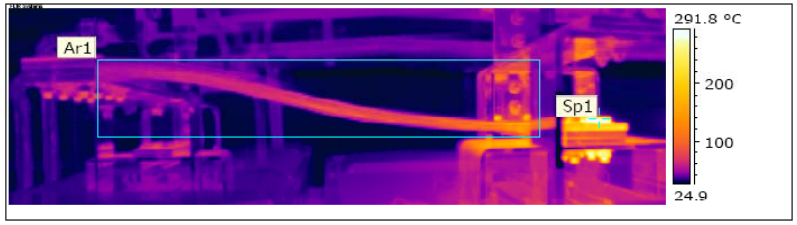
1600 filters for a total cost of nearly

- Different is the case where the Elettas suitable for the installation (UA83 being tr

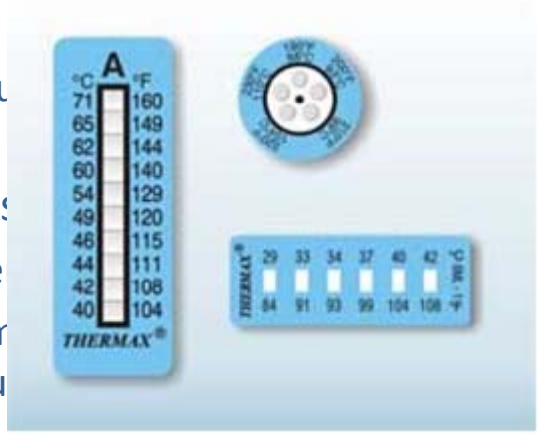
- During the HC campaign a non-conformity was discovered for which a new test step was introduce to check the correct electrical connection of the Elettas: several non-critical non-conformities were discovered and treated!

CABLE CONNECTIONS

- Facts:
  - During the SCT campaigns thermal imaging was many times used to look for hot spots on DC cable connections



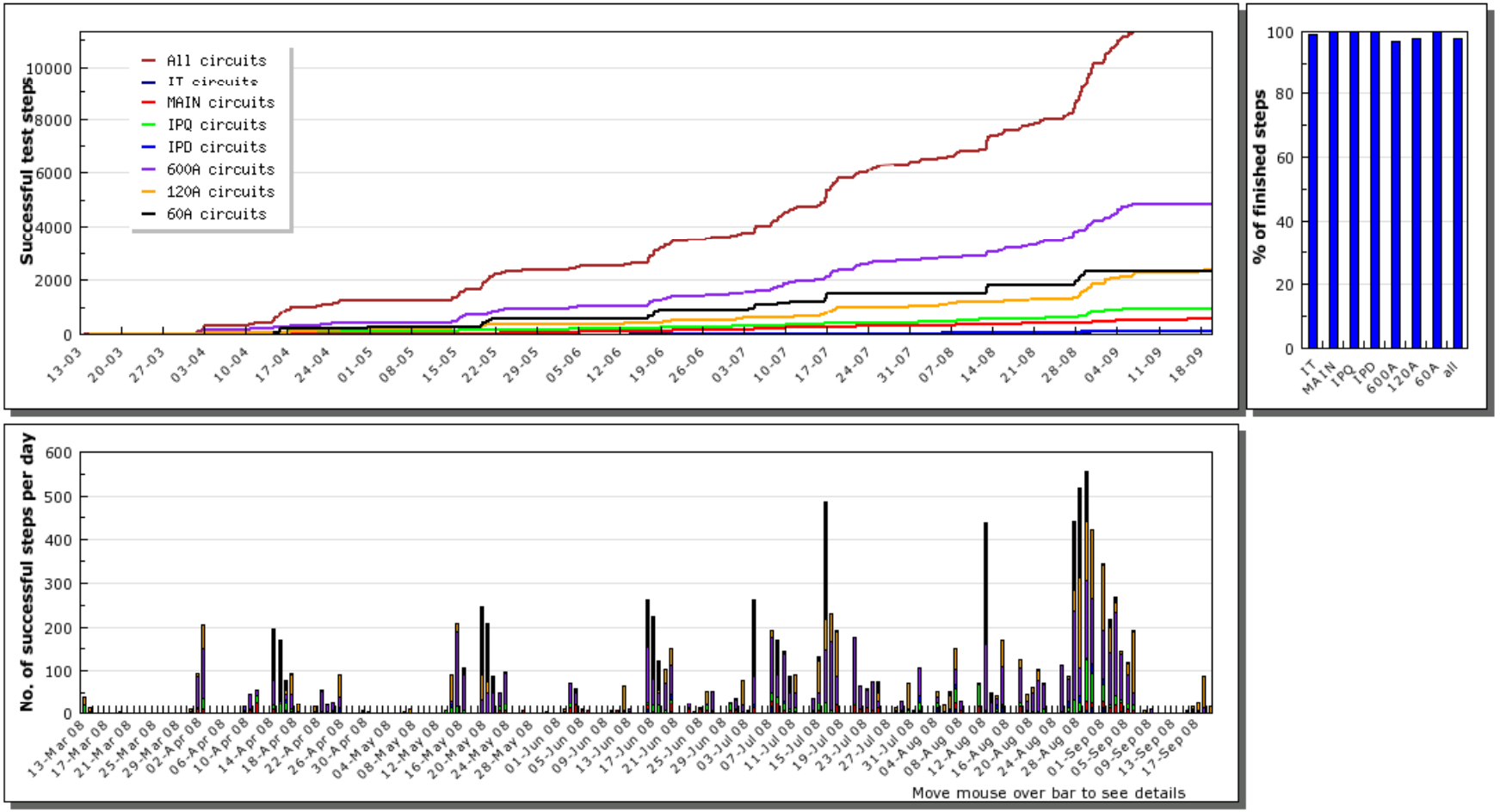
  - Cables are sometimes disconnected (ElQA on DFB, power converter check, etc.) and a re-qualification is needed
  - On August 15, a 6-kA circuit was powered with a loosen cable connection on the DFB side, with the result of a high temperature increase of the connection and consequently of the HTS part (up to nearly 80 K)
- How to avoid current lead over-heating in the future?
  - An alarm, based on temperature reading on current leads, is already availabel and a software interlock is being developed
  - The installation of thermo-switches has just been discu solution (link either to QPS, PIC or PC) is not yet defined



- How to deal with time-to-time checks (i.e., after cable di
  - The phenomenon is, of course, more relevant at high curre
  - Safety issues raised after S34 incident has been/will be m more severe, possibly preventing people in the undergrou high current

➲ **"Thermo-strips" could be used for spot checks after short high-current runs**

Summary of executed test steps in all sectors



11122 out of 11321 test steps successfully executed

CONCLUSIONS

Sector 1-2

Circuit Type	Total number of circuits	Commissioned to 7 TeV	Commissioned only to 5 TeV	To be commissioned
RB, RQ	3	-	3	-
IPQ, IPD	31	31	-	-
Triplet	2	2	-	-
600A	53	36	15	2
80-120A	50	50	-	5
60A	94	94	-	-
TOTAL	**237**	**212**	**18**	**7**

Sector 2-3

Circuit Type	Total number of circuits	Commissioned to 7 TeV	Commissioned only to 5 TeV	To be commissioned
RB, RQ	3	-	3	-
IPQ, IPD	16	16	-	-
Triplet	1	1	-	-
600A	56	32	22	2*
80-120A	37	37	-	-
60A	94	94	-	-
TOTAL	**209**	**182**	**25**	**2**

Sector 3-4

Circuit Type	Total number of circuits	Commissioned to 7 TeV	Commissioned only to 5 TeV	To be commissioned
RB, RQ	3	-	2	1
IPQ, IPD	8	8	-	3
Triplet	-	-	-	1
600A	50	27	-	23
80-120A	22	20	-	2
60A	94	94	-	-
TOTAL	**177**	**174**	**3**	**19**

Sector 4-5

Circuit Type	Total number of circuits	Commissioned to 7 TeV	Commissioned only to 5 TeV	To be commissioned
RB, RQ	3	-	3	-
IPQ, IPD	16	16	-	-
Triplet	1	-	-	1
600A	47	33	-	14
80-120A	35	31	-	4
60A	94	94	-	-
TOTAL	**196**	**174**	**3**	**19**

Sector 5-6

Circuit Type	Total number of circuits	Commissioned to 7 TeV	Commissioned only to 5 TeV	To be commissioned
RB	1	-	1 (6.61 TeV)	-
RQ	2	2 (11280 A)	-	-
IPQ, IPD	12+1	12+1	-	-
Inner Triplet	1	1	-	-
600A	46	19	25 + 2 (<5TeV)	-
80-120A	33	29	3	1
60A	94	94	-	-
TOTAL	**190**	**160**	**29**	**1**

Sector 6-7

Circuit Type	Total number of circuits	Commissioned to 7 TeV	Commissioned only to 5 TeV	To be commissioned
RB	1	-	1	-
RQ	2	-	2	-
IPQ	5	5	-	-
600A	49	21	28	-
80-120A	20	20	-	-
60A	94	94	-	-
TOTAL	**171**	**140**	**31**	-

Sector 7-8

Circuit Type	Total number of circuits	Commissioned to 7 TeV	Commissioned only to 5 TeV	To be commissioned
RB, RQ	3	-	3	-
IPQ, IPD	9	9	-	-
Triplet	1	1	-	-
600A	56	34	21	1
80-120A	37	32	-	5
60A	94	94	-	-
TOTAL	**200**	**170**	**24**	**6**

Sector 8-1

Circuit Type	Total number of circuits	Commissioned to 7 TeV	Commissioned only to 5 TeV	To be commissioned
RB, RQ	3	-	3	-
IPQ, IPD	17	16	1	-
Triplet	2	2	-	-
600A	53	51	-	2
80-120A	50	38	-	12
60A	94	94	-	-
TOTAL	**219**	**201**	**4**	**14**

Thanks for your attention!