Changes in QPS

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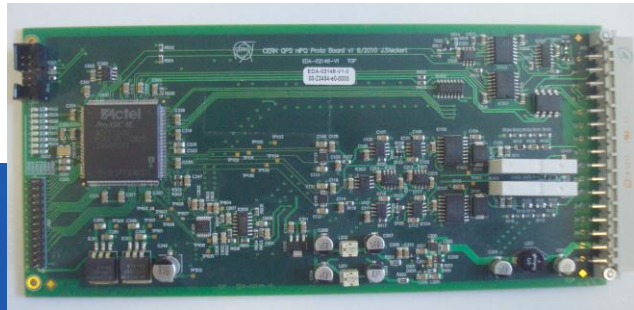
1st change – trying to use new CERN corporate identity

Introduction

- Major upgrades can only be smoothly implemented during long shutdowns
  - Re-furbished / upgraded systems should be able to run without major overhaul at least for 3 to 4 years
- No principal change of the protection functionality required for the LHC after LS1
  - Some protection settings to be adapted to higher energy
- Several requests for enhanced supervision & diagnostic capabilities by equipment owners, experts and users
  - Requested for LHC operation as for hardware commissioning
  - Enhanced remote control options, less accesses, more automatic analysis and maintenance tools, configuration databases
- R2E consolidation to be completed
- General system overhaul

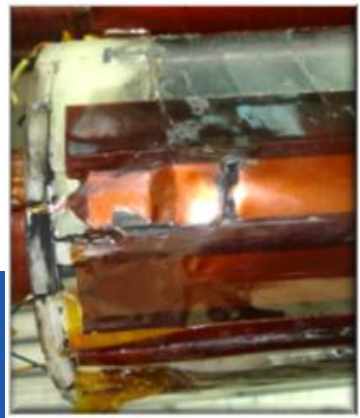
R2E consolidation

- Relocation of QPS equipment
  - Concerns the inner triplet protection systems installed in UJ14, UJ16 and UJ56 (12/35 dumps in 2012)
- Deployment of radiation tolerant hardware
  - IPQ & IPD protection (RR13,17, 53, 57)
    - One system successfully tested in 2012/2013 (Q6.L5)
  - 600 A protection (RR13,17, 53, 57, 73, 77)
    - Development to be completed → upgrade is mandatory
  - Enhanced power-cycle options for DAQ systems including automatic re-start of stalled field-bus couplers
    - Intermediate solution until NanoFip based DAQ systems are available



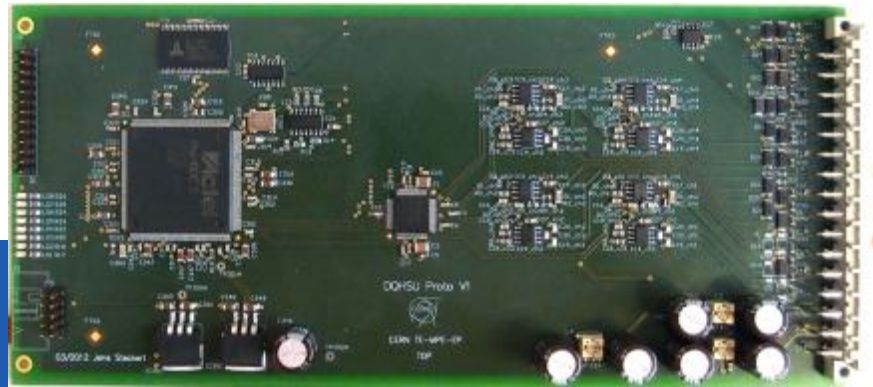
Enhanced quench heater supervision I

- The upgrade is driven by the intention to reduce the risk of damage to the quench heater circuits
  - The present system monitoring only the discharge voltage is not sensitive enough to detect all fault states of the quench heater circuits especially failures of the heater strips.
  - All of the few quench heater faults observed so far during LHC operation could be mitigated by disabling the respective heater circuit and switching to a low field heater.
  - There is however a risk of a quench heater fault requiring at least an exchange of the magnet (short to coil, compromised electrical integrity of the magnet)



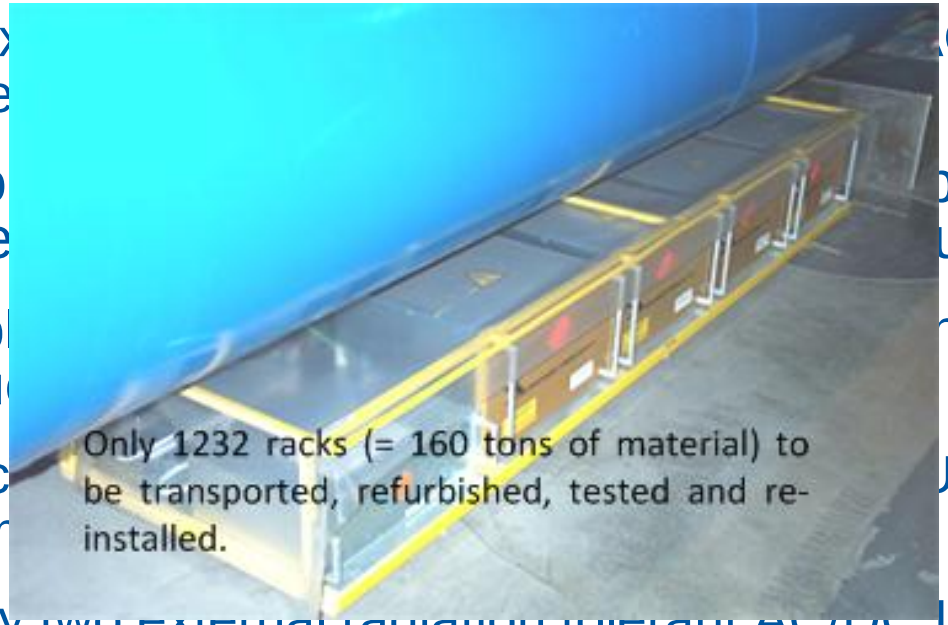
Enhanced quench heater supervision II

- The enhanced quench heater supervision is supposed to reveal precursor states of a potential failure
- The newly developed system records simultaneously the discharge voltage and current
  - Sampling rates up to 192 kHz, 16 Bit resolution
  - Special mode to detect blown internal fuse of the quench heater power supply → potential heater isolation fault
  - Requires development of sophisticated high level software to analyze post mortem data



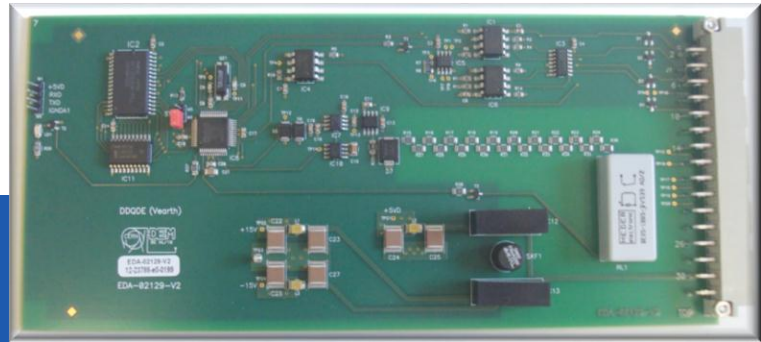
Enhanced quench heater supervision III

- The present protection crates cannot be extended to house additional measurement systems
  - The ex Q systems can be re-use
- Protectio be refurbished complete utside LHC
  - Compl ned, validated, produ
  - New c UPS powering schem
  - Fed by two external radiation tolerant AC/DC LDO converters
- Major upgrade requiring significant effort
  - Still on track but it may become necessary to postpone some other less important activities



Earth voltage feelers for LHC main circuits

- The earth voltage feelers will monitor the electrical insulation strength of the LHC main circuits especially during fast discharges
  - The system will as well measure the electrical insulation strength between adjacent bus-bars
  - As all data will be stored in the LHC logging database also the evolution in time can be studied. In case of an eventual earth fault the system will allow to identify the location of the fault position on the half-cell level.
  - Per sector a maximum of 54 devices for the main dipole circuit and 55 for each of the main quad circuits can be installed (1308 units in total).



General system revision I - hardware

- QPS systems have been exploited since 2007
  - Designs and firmware dating back to 2002
  - No major hardware change a part the nQPS extension
  - Replacement of obsolete systems, upgrades with improved or enhanced functionality
- IPQ and IPD protection (mandatory)
  - Upgrade of warm instrumentation cables for Q9 & Q10 to achieve better immunity against electrical perturbations
  - Fix non-conformity in QPS / DFB instrumentation interface
    - Unique interface required
  - Detection hardware to be updated and unified
    - nDQQDI board, so far SEU and near miss free

General system revision I – hardware continued

- 600 A protection (partly mandatory)
  - Deployment of radiation tolerant detection systems in RR
  - Implementation of a hardware multi-trigger option for the DAQ systems
    - Eases hardware commissioning, assures that all post mortem data are sent
- Quench loop controller upgrade (optional)

Note on QPS quench loops for LHC main circuits:
Proposed upgrade is for enhanced diagnostics and easier maintenance only. During LHC run 1 the quench loops were extremely reliable; there is no evidence at all for a malfunction or spurious trigger caused by the loop itself.

gers

aults

inside the current loop

General system revision II – Energy Extraction

- Arc chamber installation for RQD/RQF extraction switches to be completed in order to increase the maximum operational voltage of these circuits
  - Will allow to keep the discharge time constant of the RQD/RQF circuits short (t < 20 s)
  - At the same time the installation of the snubber capacitor banks in the RQF/RQD Circuits (16 installations) will be executed
- 600 A energy extraction systems
  - Implementation of a general upgrade campaign, including an improved fixation of the holding coils and supervision of the internal current distribution
  - Firmware update of interface board to fix vulnerability to non-conform user manipulations

General system revision III – firmware

- General revision of detection system firmware
  - Fixing of some vulnerabilities revealed during the last years
  - Compatibility with remote access to device parameters (read and write)
  - Adapt supervision resolution and sampling rates to actual hardware capabilities
- Upgrade of QPS low level supervision
  - Full visibility of redundant circuit boards including post mortem buffers
  - Some bug fixes (e.g. timing problems) and code optimization
- Update is tedious as many circuit boards need to be re-programmed

General system revision IV – QPS supervision

- Major change in the physical layer of the QPS field-bus by doubling the number of segments
  - Allows to increase data transmission rate by almost a factor two by reducing the macro-cycle length to 100 ms
- Transmission of QPS data to logging database to be improved
  - On change recording or filtering of analog signals no longer permitted
  - States must be interpolated for retrieval
  - Allows much easier analysis and detection of eventual hidden fault states
- Firmware download and update via the QPS supervision under investigation
  - Not straightforward; requires quite a number of changes

General system revision V – QPS supervision high level tools

- The full exploitation of all QPS upgrades presented so far requires a series of new high level supervision tools (MS section)
  - Enhanced quench heater supervision data analysis
  - [illegible]tance
- [illegible] during LS1
  - Automatic check of all device parameters
  - Automatic download of some parameters, e.g. download of nQPS compensation coefficients after a hardware change
  - Critical parameters can only manually set by experts

Dependency of QPS systems on human interaction to be further reduced as principal cause for near misses during LHC run 1.

General system revision VI – quench detection settings revisited

- Revision of **THE THRESHOLD of 100 mV** is long overdue
  - Increases system dependability significantly, reduces machine downtime, spares the superconducting circuit …
  - Especially necessary for "tricky" circuits like the 600 A and some IPQ etc.

By the way (just a coincidence?) … from Wikipedia:
"Endo cochlear presentation is the positive voltage of 80-100mV seen in the cochlear endolymphatic spaces."

- Even with the revised settings none of the 600 A circuits can be protected without inductive compensation
  - Longer evaluation and higher threshold voltage are however especially beneficial for the development of radiation tolerant systems.

Re-commissioning and operation after LS1

- All the work performed during LS1 by will require a full re-commissioning of all protection systems prior to the powering tests
  - Complete electrical quality assurance for all superconducting circuits
  - Test of all QPS instrumentation cables (very critical activity)
  - Complete individual system tests: interlock tests (**all** 13722, quench heater discharge tests etc., verification of data transmission
- The re-commissioning will profit from the experience gained so far but will remain challenging (as usual)
- Additional tests will be required during the powering tests in order to qualify some newly installed items

Re-commissioning and operation after LS1

- System exploitation will change significantly after LS1
  - Teething problems during initial exploitation phase to be expected (otherwise something is really wrong …)
  - Longer turn around time after trips; more real triggers
  - Almost all circuits will operate outside self-protecting regime
- Efficient training of service teams (MPE stand-by, MP3 ..) is essential and has to start soon
  - Integration of new members, get people familiar with upgraded systems
  - After initial phase less but more complex interventions of the stand-by service expected → will require a substantial training effort

Summary

- The upgrade of the QPS systems during LS1aims to increase the system dependability and to enhance the diagnostic capabilities
  - Successful upgrade will reduce machine time significantly, especially radiation induced trips and allow much more preemptive fault diagnostics
  - Substantial effort to improve maintainability (more remote control etc.)
- **Major** upgrade of the QPS only possible during LS1
  - So far on track but not much room to manoeuvre
  - Upgrades and projects not yet defined will cause delays
- Sufficient time for testing and re-commissioning including some contingency required
  - Eventual savings in time during commissioning will need to be repaid during operation with interest and compound interest …