LHC RF: plans for the next long shutdown (2012/13)

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Summary

- High power RF system
- SC cavities
- Transverse Dampers

  - Problems or weaknesses identified so far
  - Possible solutions/upgrades
  - Possible consequences if next shutdown is postponed to 2013

HPRF: silicon oil reconditioning

- must be done every 5-6 years:
  - 24 high voltage tanks (klystron modulators, crowbars): ≈ 300 l each
    - Tanks were filled in with oil in 2006
  - Relatively long process:
    - Cannot be done “in situ”
    - HV tanks must be:
      - Disconnected
      - Transported
      - Reconditioned
      - Re-installed, re-connected
      - Re-tested (crowbar test in particular)
  - Oil quality tests are performed every year (since 2009)
    - No degradation observed so far
    - Not a big deal if long shutdown postponed by a year

HPRF: thyratrons replacement

- Klystron's fast protection system (crowbar) uses thyratrons:
  - role:
    - Reduce the HV from 58 to 0 kV in less than 1 µs
    - Discharge currents:
      - Discharge of the 600m cable capacitance & 4 µF smoothing capacitor: short sharp 6 – 8 kA pulse
      - Discharge of the large 2 x 2.5 H inductors : long ≈ 60 A , 350 ms pulse
  - thyratrons:
    - Do a good job but some reliability problems (auto firing):
      - Require very fine adjustment of all four heater currents -> small drifts with time -> loss in reliability (1-2 trips per week)
      - Very sensitive to noise, in particular on the "earthing" system
  - we are currently investigating solid state replacement solutions
    - Plan:
      - Develop, test & validate new solution in 2011
      - Eventual implementation in 2012
        - requires quite important modification of the crowbar system
        - can be done gradually => does not depend on the long shutdown

HPRF: tetrodes replacement (1)

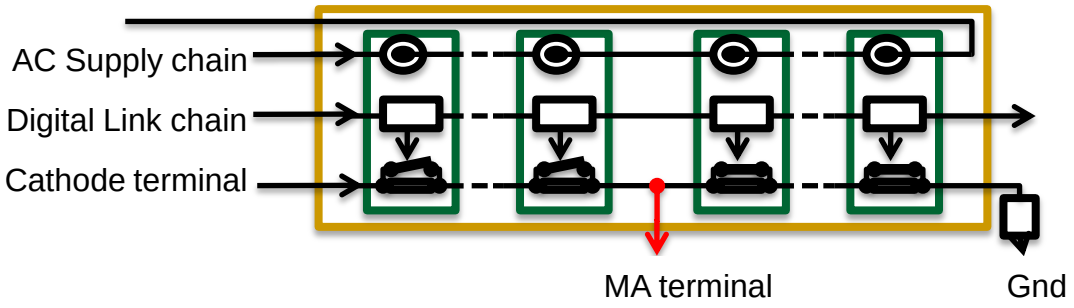
- The klystron current is controlled with a “modulation anode”
  - Each power converter feeds four klystrons
  - Klystron power can be individually adjusted
- The klystron modulators are equipped with:
  - Klystron heater transformer
  - Measurement circuitry
  - Tetrode, use in the modulation anode divider
    - Tetrode lifetime is limited
      - 2010: 4/16 tetrodes replaced!
    - Tetrode production is almost stopped

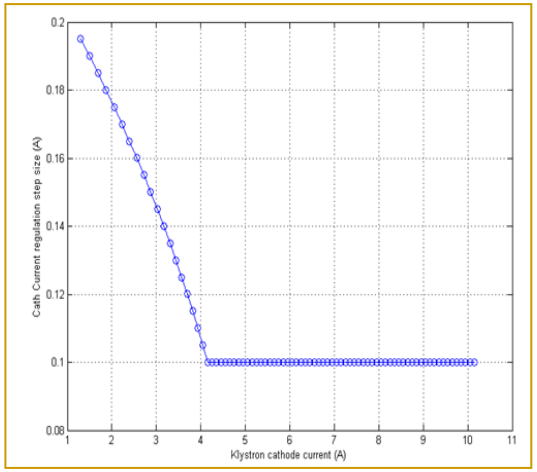
=> replacement solution is necessary

HPRF: tetrodes replacement (2)

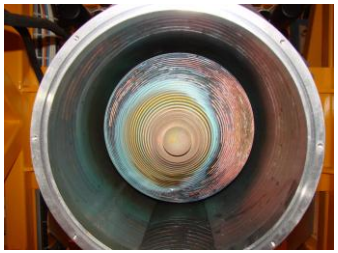
- New Modulating anode system based on a “solid-state” solution (D. Valuch)
  - will provide 0.1 A cathode current regulation steps in the active region (~100 reed relays)
  - will give us much better access to the HV measurements (heater current and power, cathode current, MA current)
- A prototype unit has been being developed and built
- Should be tested & validated in 2011
- Implementation in LHC can be done progressively

=> does not depend on the long shutdown

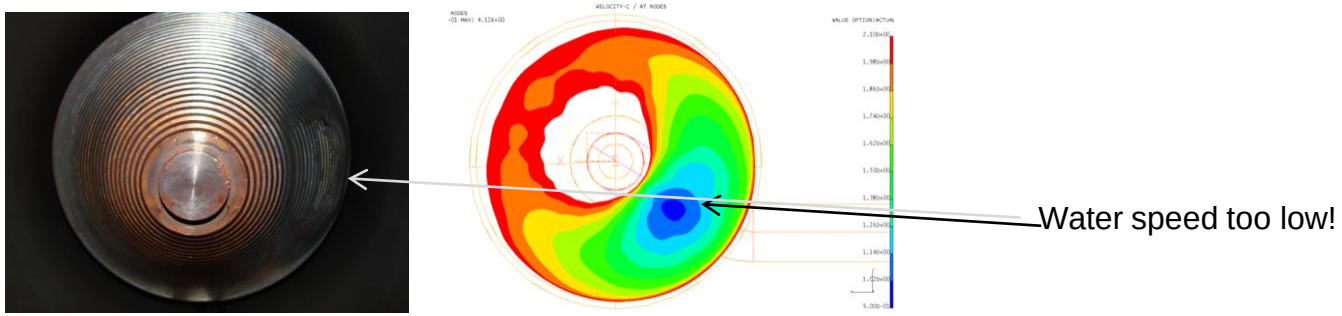




HPRF: klystron collectors (1)



- History:
  - 2007: premature death of a klystron -> vacuum leak due to overheating of the collector
  - Inspection of other collectors also showed signs of overheating-> bad design of the Thales klystron “boiler” (water jacket)



  - A new design was tested & validated (Thales) and all klystrons were modified in 2008
  - Further inspection done during the 2009 – 2010 shutdown on two klystrons showed that the problem was solved (signs of overheating still observable after long running period)

=> DC power limited to 50 kV, 8A

  - 2010: boiler re-designed and modified by Thales, and tested at CERN

=> successful 200hrs test: no heat spot detected

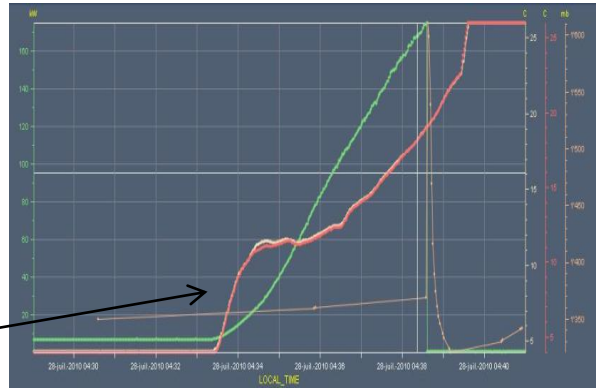
HPRF: klystron collectors (2)

- Four boilers have been replaced during the present shutdown (≈ 4 weeks)
- DC power still limited to 50 kV, 8A for the other 12 klystrons
  - Planning:
    - If long shutdown in 2012 => replace them all
    - If short shutdown => replace 4 (or 8?)

Superconducting cavities

- Tuning systems:
  - Check the mechanics of the tuning system (inside cryostat) (after cable replacement in 2009)
  - Will be done as soon as there is a long shutdown (no problem observed in 2010)

- Cavity 3 beam 2:
  - Strong field limitation @ 2.2 MV is observed
    - Sharp He pressure spikes
    - Radiation goes up significantly
  - Very stable ≤ 1.2 MV but unpredictable behavior above 1.2 MV
    - Long stability periods interrupted by sudden He pressure spikes
    - Temperatures increase of one of the four HOM antennas
  - Multipactor at the cavity equator could be the culprit



Need conditioning time to investigate

=> if not successful, we could envisage replacing the module during next long technical stop

- 2 months (RUX45 roof, vacuum people, …)

Transverse dampers – RF pickups & pickup cables

Repair:

- Replacement of damaged pick up cables (Q7, Q9):
  - max 16 cables from tunnel to SR4 (surface), damaged during LHC installatio
  - consequences:
    - The impulse response suffers of periodic reflections which distorts the pickup signals degrading the signal quality.
    - worst segments were already replaced last year
    - may affect/limit the ADT system performances with short bunches spacing & high intensity beams

Upgrades:

- Additional pick ups (Q8, Q10 or warm section), incl. cables:
  - 16 cables from tunnel to SR4 (surface)
  - upgrade towards further reduction of the signal/noise performance of the whole ADT system

Transverse dampers – RF cables upgrade (to 7/8” flexwell)

Upgrades ..:

- Power amplifier RF drive cables:
  - replacement of 32 cables from UX45 to UX451 (ADTs) + 8 cables from UX45 to SR4 (surface)
  - benefit:
    - reduction of crosstalk between bunches
    - upgrade towards stronger, cleaner & sharper pulses for abort gap cleaning for higher frequencies (up to 20MHz)
  - impossible to pull 32 new cables without drilling new holes between UX45 and the tunnel…
  - the 8 cables from the surface to the tunnel contribute to about 80% of the expected gain of this upgrade

- HOM observation & diagnostic system:
  - used to observe interaction between the transverse dampers and the beam, on a bunch to bunch basis
  - 32 cables from UX45 to UX451 (ADTs) + 8 cables from UX45 to SR4 (surface)
  - benefit:
    - improve signal quality, crucial for ADT setting up and diagnostics
  - this upgrade can profit from the drive cable upgrade (same cable routing)

Conclusions

- High power RF system
  - 12 klystrons will be limited to 50kV, 8A until the “boilers” are replaced
    - will be completed during the next long shutdown

      => cavity field limitation
- SC cavities
  - one cavity with limited performance -> eventual replacement during the next long shutdown

    =>too early to say, need further investigation
- Transverse Dampers
  - the damaged pick up cables must be replaced asap (long shutdown required)

    => may affect/limit the system performance with short bunch spacing
  - upgrade campaign is envisaged to further improve the ADT system performances (long shutdown required)
    - higher gain/kick strength
    - improved signal quality (setting up and diagnostics)