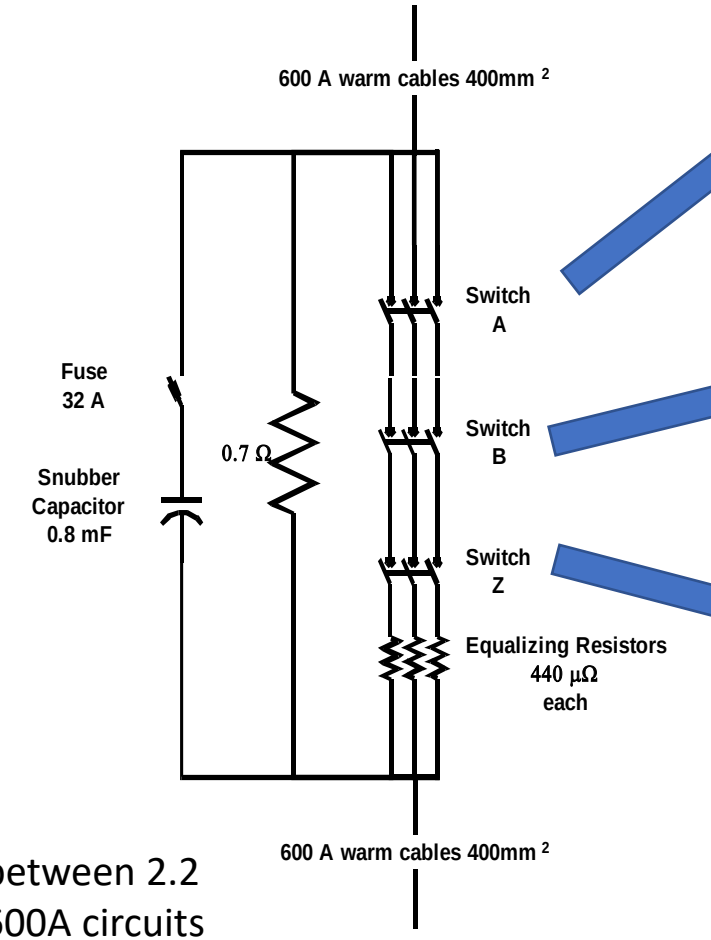
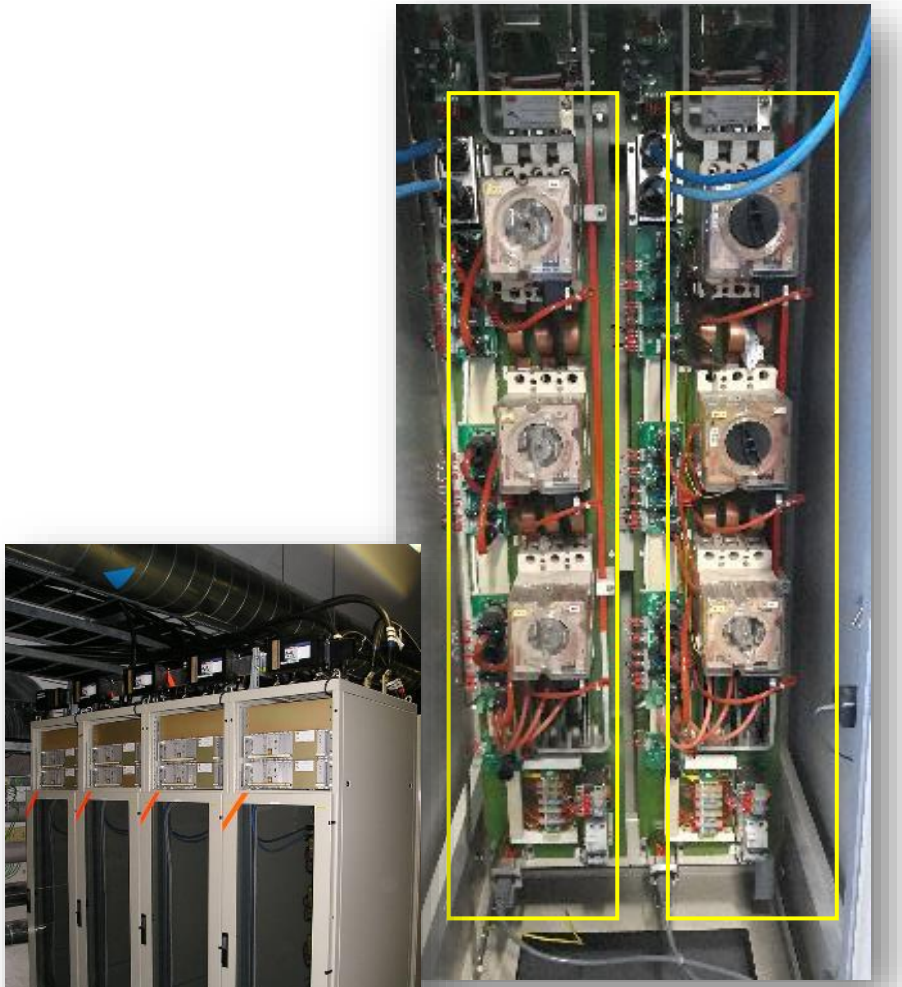
DC Contactors as switching elements for 600A EE Systems

S. Pemberton, G-J. Coelingh, J-E. Aas

TE-MPE-MP

- 600A EE system overview

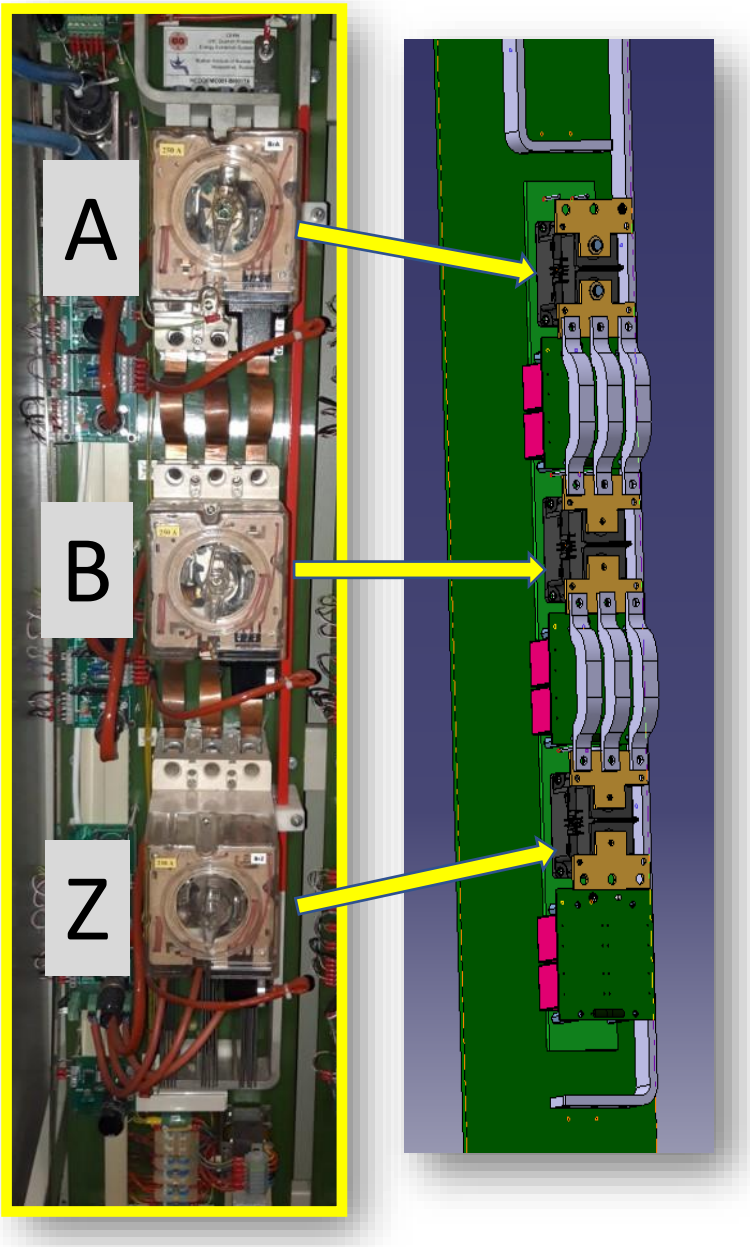




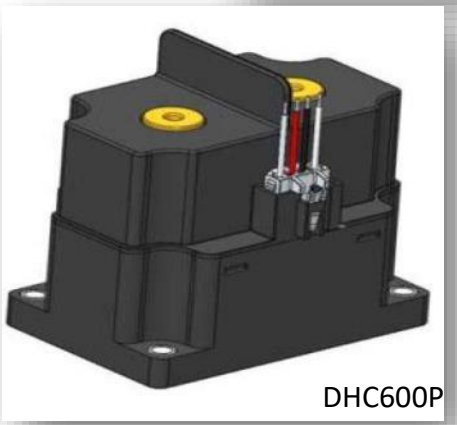
Stored energy between 2.2 and 150 kJ for 600A circuits

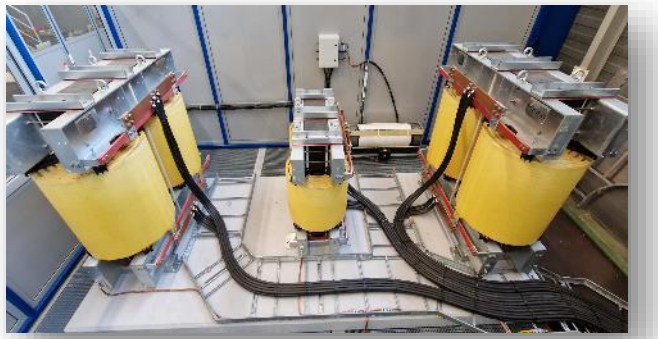
202 systems in the LHC with 2 systems per rack

- 600A EE systems in operation since 2010 – Russian design
- End of life for the current EMCB 2026 – 2030
- Reliable replacement required:
  - Fast Opening: ≤20ms
  - Continuous DC current: ≥ 600 A
  - Power cycle lifetime: ≥ 2000 cycles (1000 = 20 years LHC operation)
- Hermetically sealed DC contactors:
  - Very low cost compared to EMCB
  - No preventative maintenance required
- R&D program running over the last 3 years to find a suitable candidate:
  - Three main suppliers extensively tested
  - Rack tests:
    - Mostly steady state tests and heat runs
  - Cycle tests:
    - Endurance and lifetime tests with openings at 600A

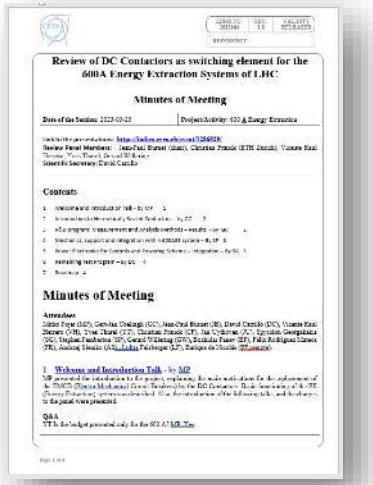


- Off the shelf models with current ratings of 600A and 1000A tested, the main candidates were:
  - Gigavac GX16, Kilovac EV600, Dongya DHC600P
- Results are extremely positive:
  - 6ms opening time
  - Current displacement 1ms, 2.5x faster than an EMCB
  - Very little arcing, snubber caps much more efficient
  - Dedicated cycle test bench built to perform cycle tests
    - 56 contactors tested – **487,878** cycles/events
    - Average lifetime all contactors combined – **7623** cycles
    - Best candidate DongyaDHC600P with average of **16112** cycles (cheapest too ☺)





- Review held in May 2023 with independent panel of internal and external experts:
  - Panel approved that DC contactors are a reliable and safe replacement for EMCB
  - Project given green light
- Price enquiry sent out October 2023:
  - Preferred candidate Dongya DHC600P provided the most attractive offer
  - 1000 pieces ordered in Nov 23 – all units were ready by Dec 15th – currently in transit
  - Reception tests will begin once the units arrive at CERN
- New Snubber caps:
  - Snubber caps will be mounted on a PCB
  - The PCB has been designed and tested successfully
  - Two manufacturers selected, price enquiry will be sent in the coming months


Review of DC Contactors as switching element for the 600A Energy Extraction Systems of LHC

Minutes of Meeting

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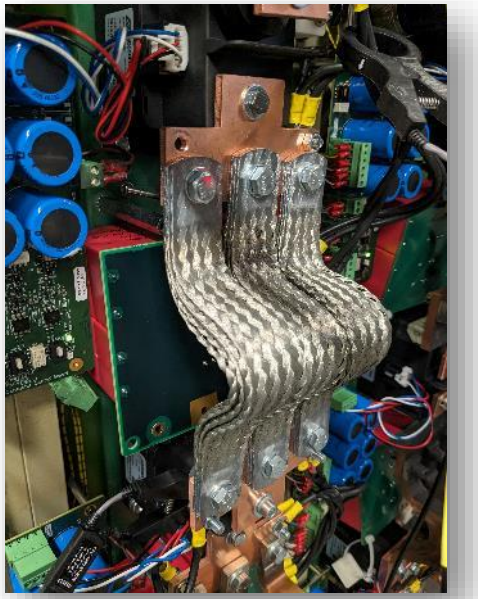
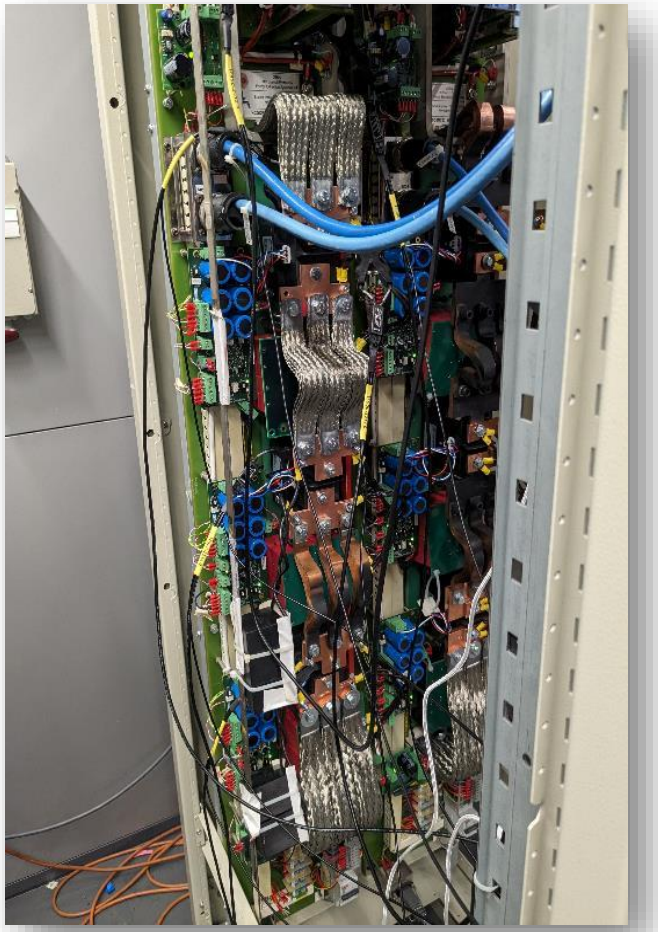
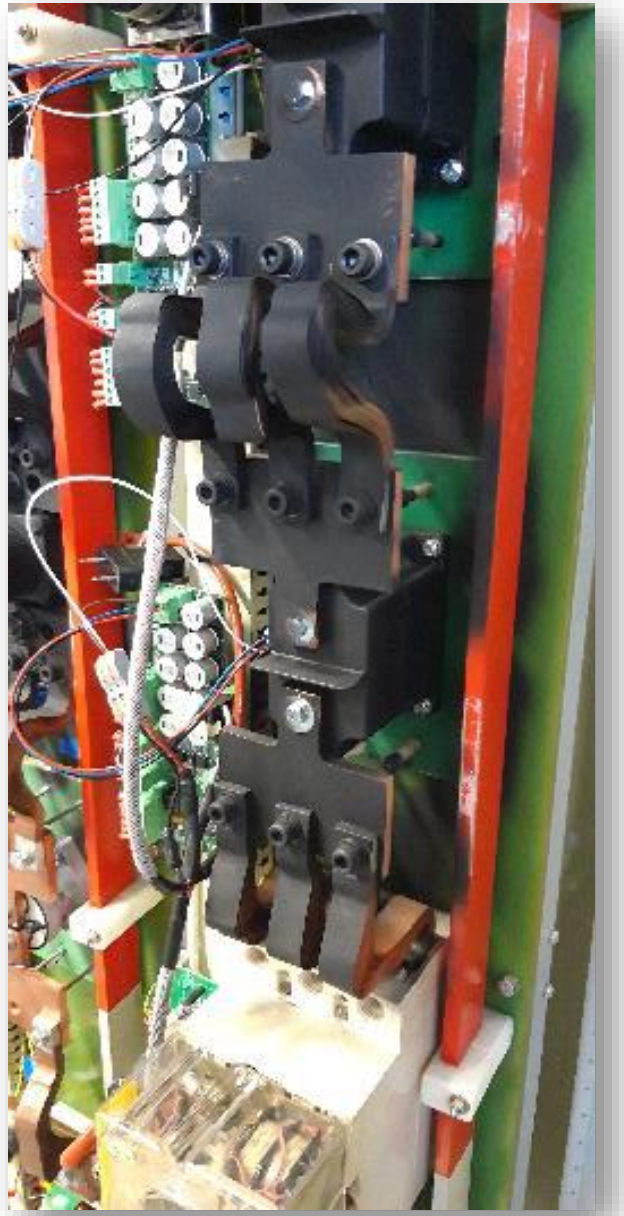
Minutes of Meeting



- Integration:
  - Replacement focuses on the principle of 1 to 1 direct replacement – ‘Plug and play’
  - No changes to the electro-mechanical infrastructure
    - Original main fixed busbars remain in place
    - Contactors to be fixed to existing fibre glass back plate in the same 3 positions as the current EMCB
    - Possible to re-use original flexible copper interconnections – large saving
  - No changes to the wiring layout
    - New power electronics PCB will be pin-compatible with the current wiring scheme and designed to directly fit with all current fixation points
  - New electronics chassis and cards to be finalised and tested
- Upgrade of systems during LS3
  - Detailed analysis to be done to optimise the removal and installation during the shutdown
    - Manpower planning ongoing for LS3
    - Pre-mount DC contactors already on a custom back panel on the surface – Prototype under test
    - Step-by-step procedures for the dismounting and installation of all equipment in the tunnel



- Timeline and further tests up to LS3:
  - Final details of mechanical integration to be developed over the coming months
    - Connection flag testing
    - Mechanical fixation of local snubber caps
  - Heat run with the final system and EMI tests
- Procurement of components and materials 2024
  - Snubber capacitors
  - Flexible copper links
- Tests with an actual magnet in SM18
  - Prepare one system/rack for SM18 to test on a cold magnet
  - Two contactors plus one circuit breaker
  - 2024 (it depends on availability of components and on SM18)
- Further irradiation tests of components
  - In 2022/2023 tested up to 2 kGy
  - From the series 4 samples will be tested to confirm results from 2023



Thank you for your attention!