MKBH sparking and retrigger – Preliminary discussion – detailed analysis and conclusions still to follow

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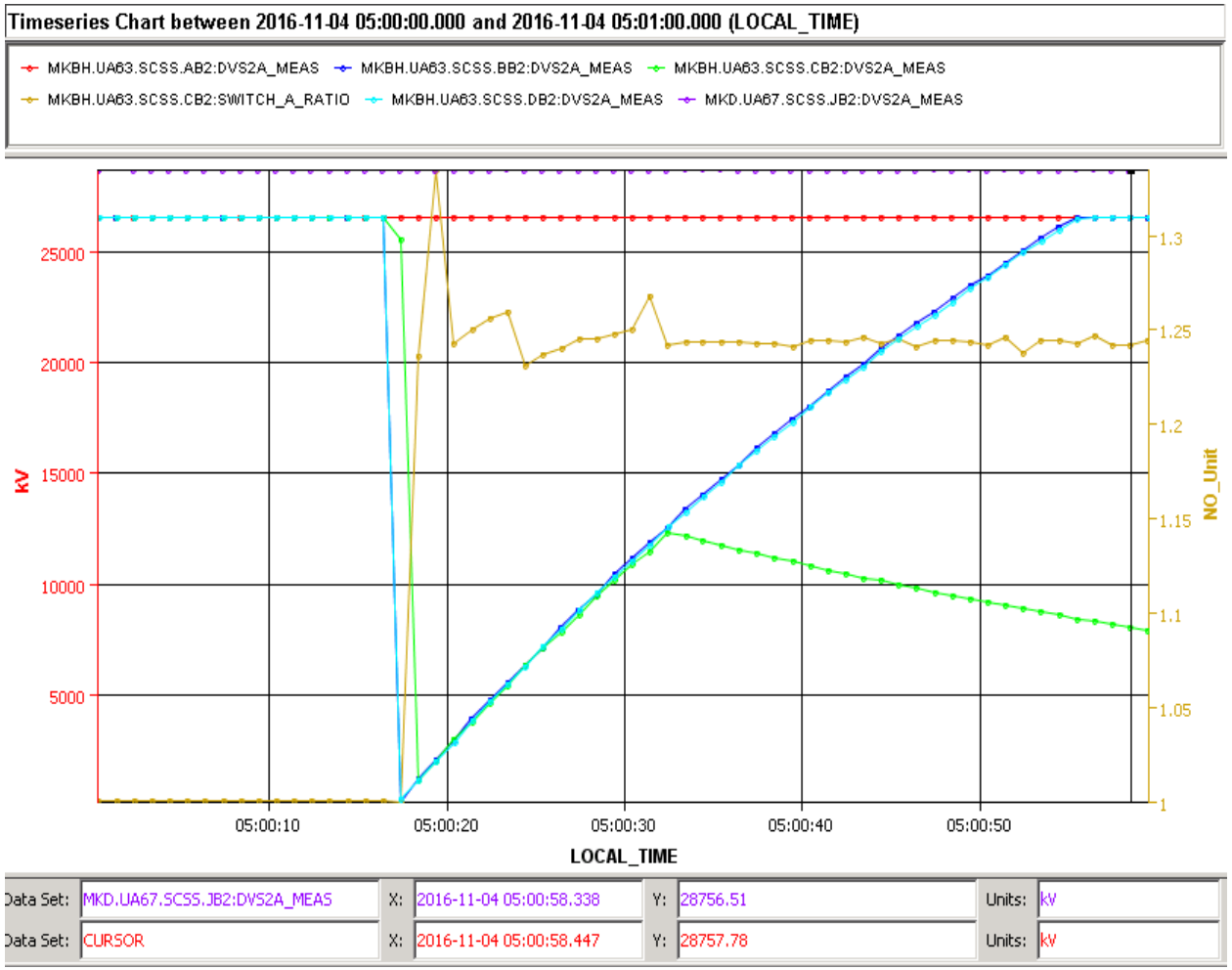
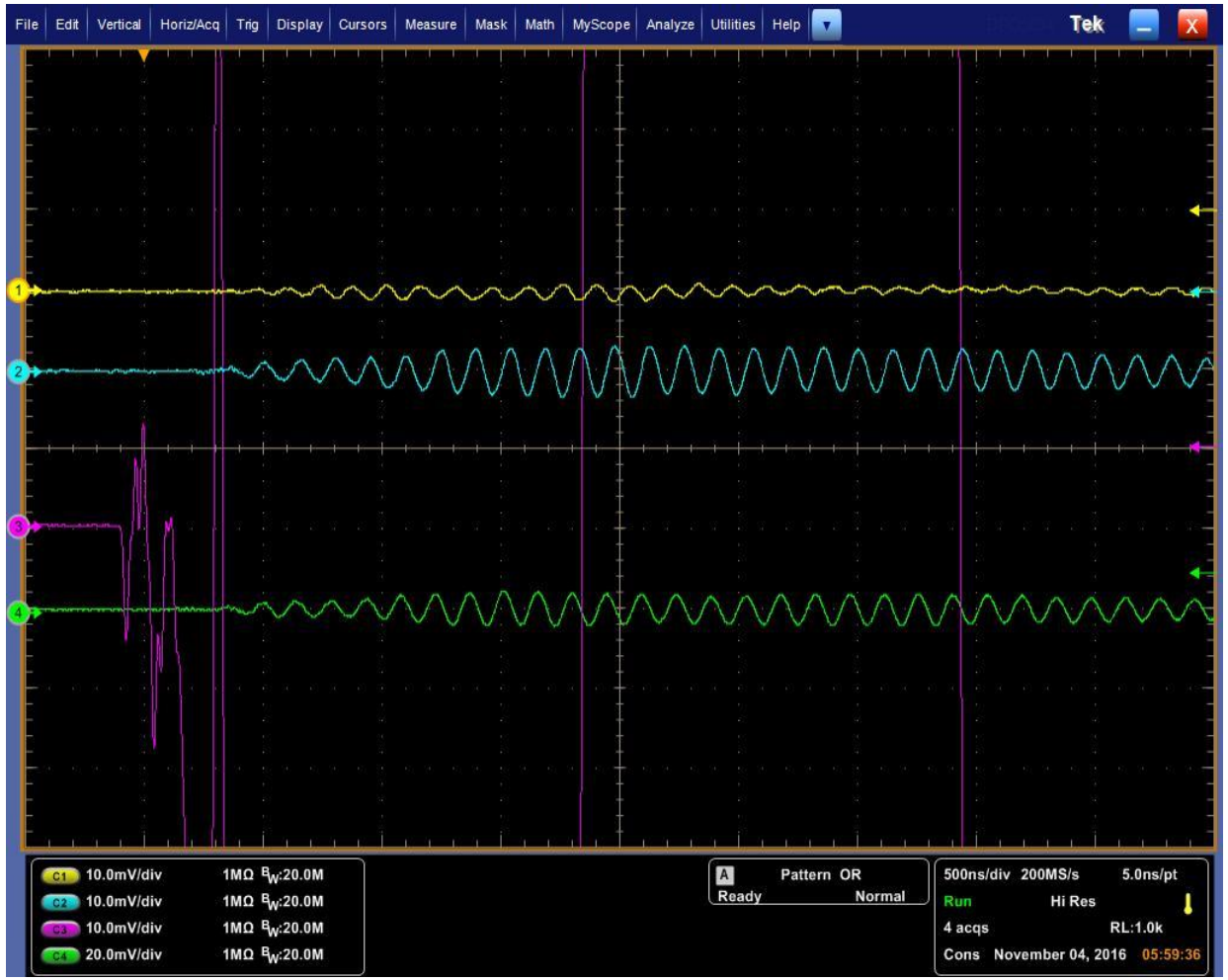
Recent experience

- Based on 2 MKBH erratic in October (01 + 04) - cleaning of all MKBH B1 + B2 during TS3 (dust penetrating by perforated panels)
- Reliability run of 4 MKBH/B1 – 0 sparks in 16 h
- Reliability run of 4 MKBH/B2: few small sparks A + B, strong spark D, erratic of C: GTO damaged
- MKBH C erratic provoked retriggering of its neighbors – MKBH B + D via retrigger line (5 to 6 us later – not captured by oscilloscope because of scope triggering hold-off time)
- Replacement of MKBH C GTO stack by a spare
- During inspection of gen. C after stack replacement - found Ross-relay with over temperature like dark color of coil insulation and black deposit on metal surface around. Same phenomenon found on gen. D but not on B. Seen on one of MKBH/B1 as well. Replacement of Ross-relay on C, cleaning of “black deposit” on C + D
- Sparking observed on MKBH D; new cleaning – including cleaning of stack insulator: even stronger sparking than before but conditioning effect observed and after ~ 1 h of conditioning no spark up to 7 TeV; probably water present in alcohol used
- Failure of Dvs2A reading during reliability test (seen on B1 already) – replacement of HV divider with its card (contact bad soldering?)
- Since divider replacement strong sparking – cleaning did not help – replacement of D; now OK

MKBH C/B2 erratic with retriggering of its neighbours

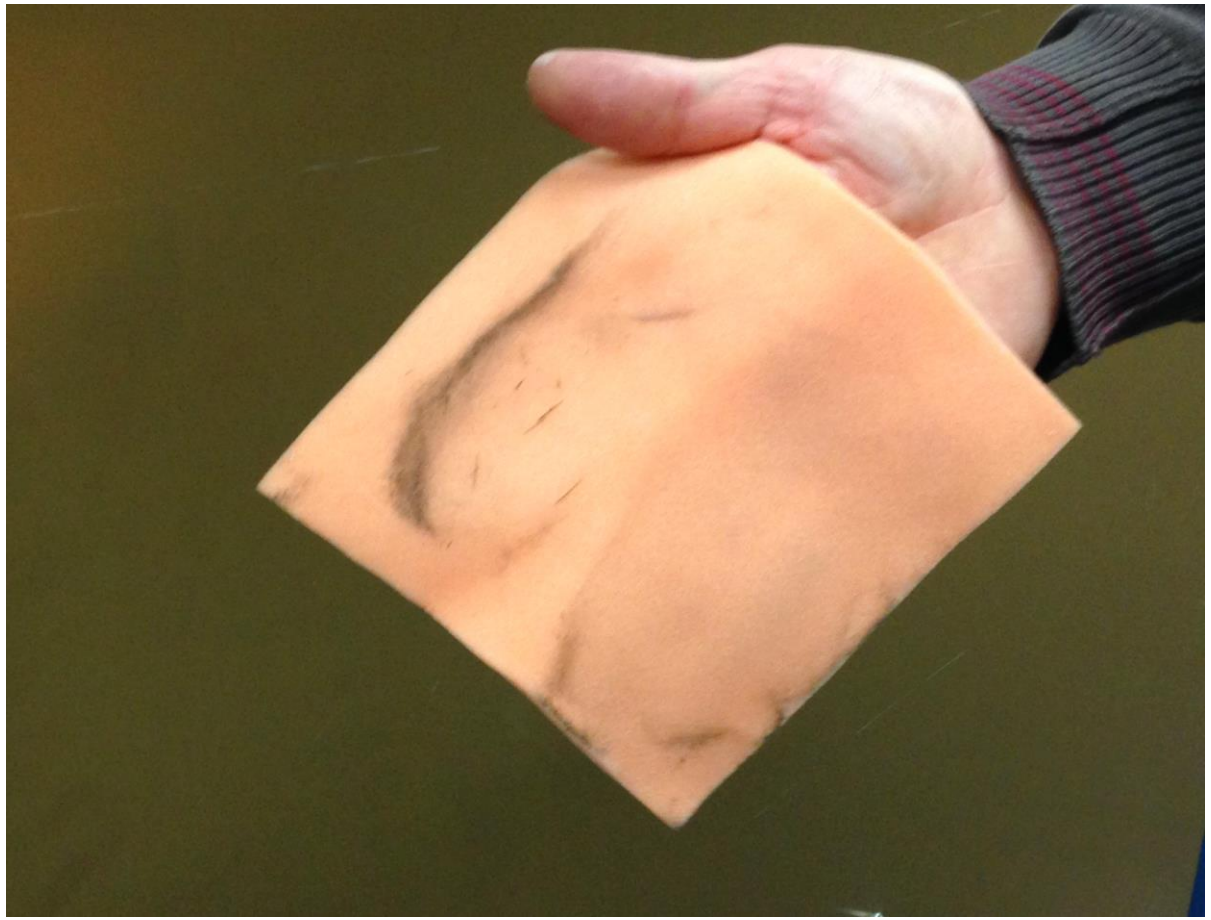




Potential sources of pollution

- Floor dust + strong VAC air blaster blowing the air above generators – dust suspension in air
- Manual earthling switch – friction of metal on vetronite almost straight above GTO stack
- Overheating (?) of discharging Ross relay with black matter deposit nearby

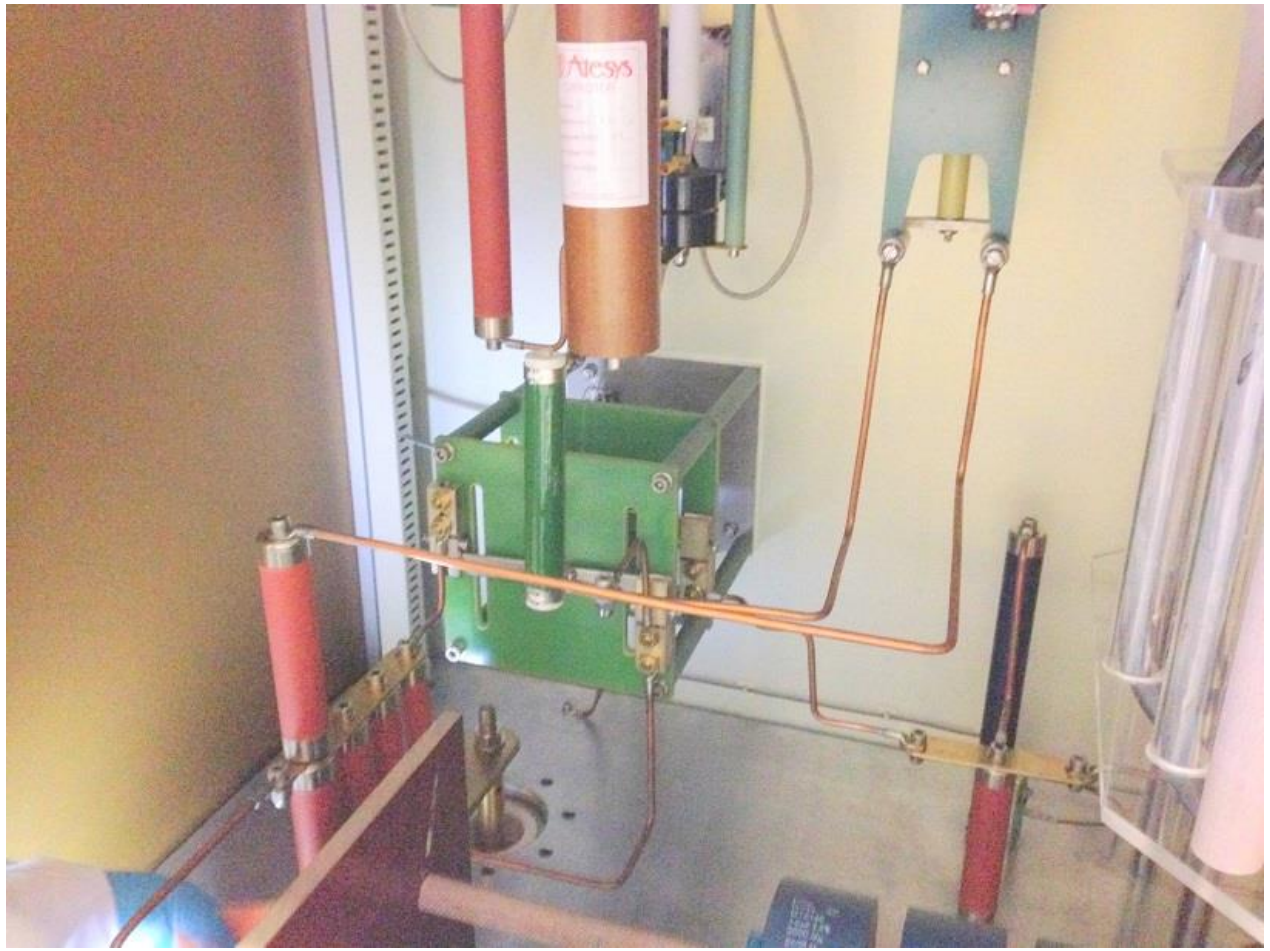
Dirt recuperated on ~ 500 cm^2 of floor in front of/underneath/on top of MKBH generator



Re-trigger of MKBH generators

- No built-in internal retrigger link from MKB toward outside
- Nevertheless, some parasitic coupling was observed:
  - Erratic of MKBH C/B2 at 7 TeV with retriggering B + D (MKD J/B2 was ON as well but not triggered)
  - Triggering of A + C at 3 TeV with disconnected trigger to B+D: gen B fired with full PTM current
  - Triggering of C at 4 TeV with disconnected trigger to A, B, D: gen. B fired but with insufficient triggering current (40A instead of 500 A nominal) – risk of damage to GTO
- Test in laboratory: Important voltage peak observed between bottom and top of generator during GTO commutation: ~ 70V at 7 TeV (according to Etienne not present in 2005)
- Consequence of connecting GTO stack bottom to generator chassis and to main copper grounding sheet under generator; 10 coax cables to magnet connected to the top; tanks in RA grounded – high inductance between UA and RA ground (return of 10 power coax cable connected to tank)
- Retrigger box metal housing is mechanically (and electrically) connected to the generator "top" ground but all electronics is referenced to generator "bottom" ground

MKBH generator



Mitigation measures

- Short term:
  - Surveillance of sparking activity of all MKBH/B2 by a remotely accessed and controlled scope;
  - Inspection of failed stack (gen. C) – non-conformities observed on principal insulator (non correct gluing) – under reparation; sparking test over weekend
  - Preparation of a spare gen. No.2 is ongoing; validation planned for beginning of the next week
  - Using of alcohol conditioned in sealed spray can (no risk of air humidity absorption)
- Middle term:
  - Replacement of perforated panels by full ones (to avoid dust penetration), EYETS – to be tested
  - Cleaning of floor in the UA63/67 in proximity/underneath of MKB generators and their chassis
  - Generator modifications (machining of sharp edges on aluminum plate, upgrade of stack HV contact (risk of metal on metal abrasion when changing the stack) – tentatively EYETS
  - Inspection of MKBH and MKD generators Ross relay (the same type) – for presence of burning traces; replacement in case of need - EYETS
  - Test of coupling to retrigger line; cabling change, insulating of retrigger box, adding ferrites?

Mid-long term cures

- Reduction of MKBH voltage to reduce risk of sparking - less total horizontal dilution
- Improved diagnostics:
  - Implementation of a MKB generator level re-trigger system
  - Deployment of additional IPOC functionalities in order to capture signals from the start of conduction and acquisition of PTU output signals
  - Adding surveillance of sparking activity on stack (already under preparation for MKD)
- Replacement of the trigger transformer with common magnetic circuit by a trigger transformer with independent magnetic circuit for each secondary “inverse inductive adder” – under development for MKD
- Upgrade of GTO stack to reduce risk of sparking – under development for MKD
- Under evaluation: 2 additional MKBH (generator + magnet) to improve dump safety in case MKBH missing or erratic. Will result in reduced voltage on GTO stack and hence strongly reduced risk of surface sparking and SEB. Fits to HL-LHC and HE-LHC mitigations and can replace R2E related measure above

Conclusion

- Erratic of MKBH/C on 04/11 at 05:00 provoked re-triggering of B + D – seen for the first time
- Experience from MKD – generators with strong spark activity generally finishes with erratic but in case of MKBH C we did not see precursor – not even weak sparking (perturbation on retrigger line?)
- Generator/GTO stack cleanness is important for voltage holding capability; Spare generator properly cleaned and tested in laboratory was completely sparking free in tunnel after replacement (sofar – dusty environment is still there)
- GTO stack from gen. C shows non-conformities – bad gluing of most critical parts of stack top insulator, sharp edges on GTO gate faston soldering…
- Investigation of coupling between generators is ongoing
- Installation of real-time air pollution monitoring might help to detect period most critical pollution generation (TS, too late filter change?)