CLIQ - experience from prototype production & fabrication status

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on behalf of the CLIQ project team

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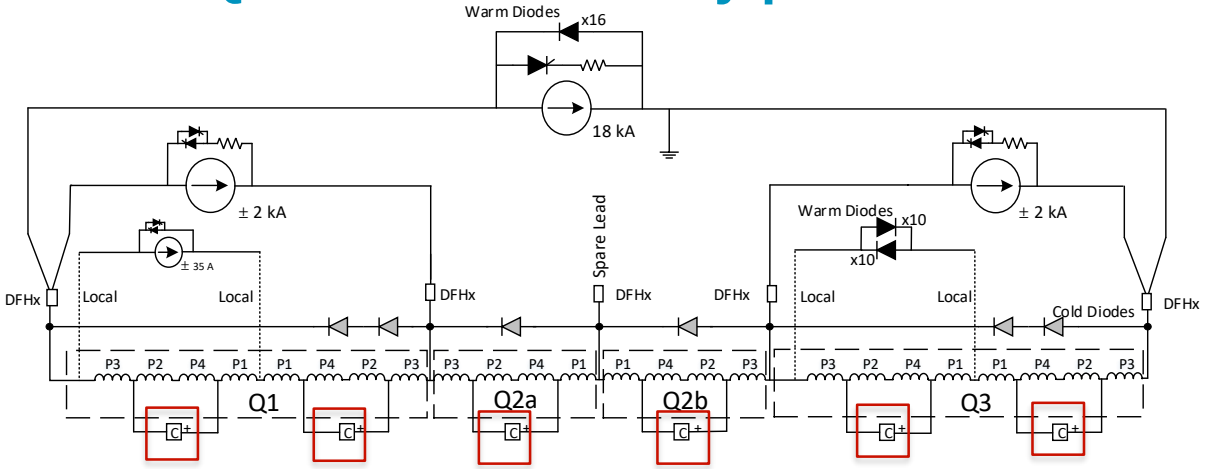
Introduction

- Coupling-Loss Induced Quench (CLIQ) is a quench protection method based on a discharge resulting in high inter-filament and inter-strand coupling losses

- **CLIQ is in the baseline of the HL-LHC** project **for the protection of the new Inner Triplet magnets** that will be installed during LS3

CLIQ. Numbers and key parameters

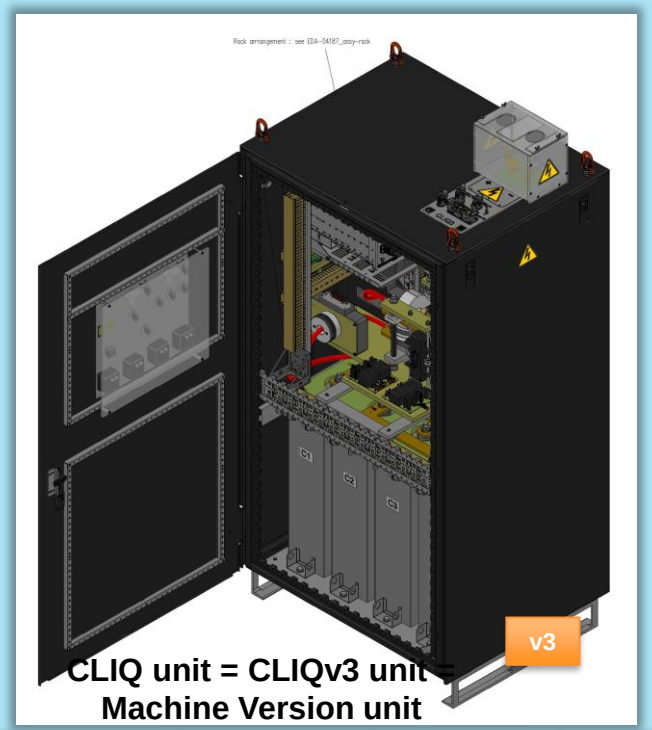


- **Q1 and Q3:** 2 CLIQ units each, with V=600 V, 40 mF
- **Q2a and Q2b:** 1 CLIQ unit each, with V=1000 V, 40 mF
- I peak ~ 2- 3 kA
- Triggering time = 1 ms
- Resistance CLIQ circuit < 50 mΩ

The Inner Triplet circuit needs 6 CLIQ units for QP (+ 48 DQHDS) per IP side

24 CLIQ in the machine
6+2 CLIQ for the String

Prototypes timeline



CLIQ unit = CLIQv3 unit = Machine Version unit

CLIQ prototypes timeline

2015 **2017** **2021**

CLIQ v3 - Machine version

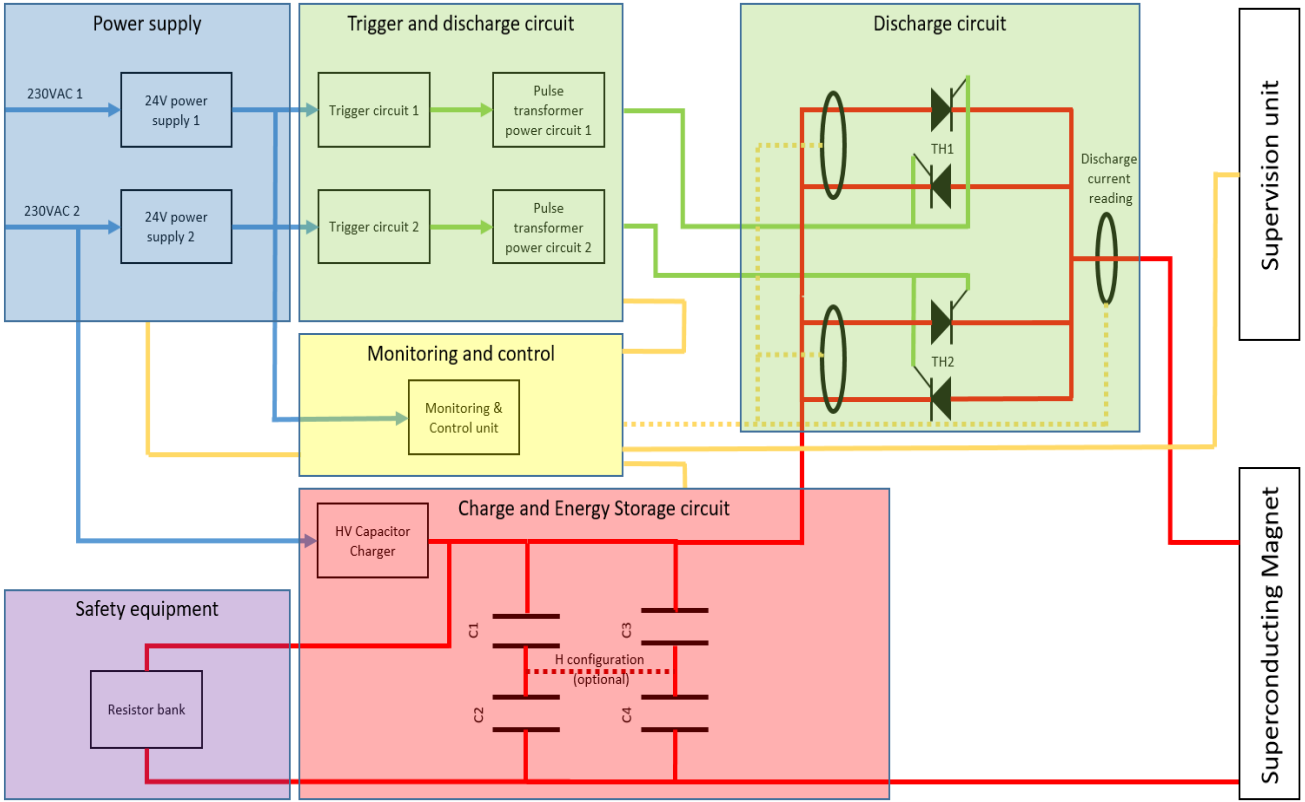
CLIQ v3
Redundant trigger

Redundant 230 VAC power supply

Capacitor bank in square configuration (4x40 mF, 1000 V DC)

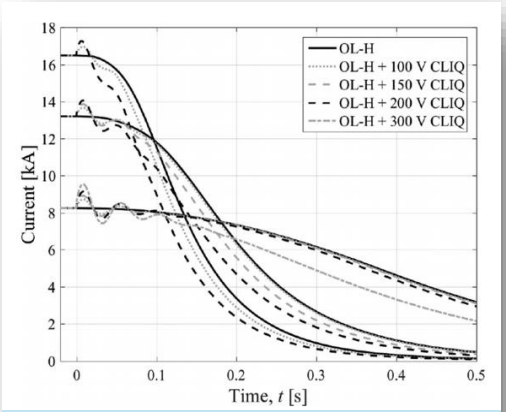
Monitoring and control unit

C=40 mF



Layout of the CLIQ machine version

Accomplished milestones



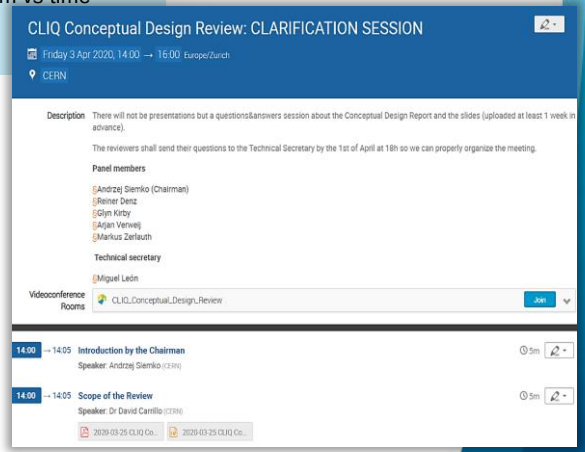
Comparison between MQXFS1b magnet discharges obtained by triggering outer-layer heaters only, or outer-layer heaters and one CLIQ unit charged to different voltage levels. Measured magnet current Im vs time

E. Ravaioli, et al. "Quench Protection Performance Measurements in the First MQXF Magnet Models," in IEEE Transactions on Applied Superconductivity, vol. 28, no. 3, pp. 1-6, April 2018, Art no. 4701606

- Extensive R&D program at the SM18 test facilities at CERN and at Fermilab with CLIQv1 and CLIQv2

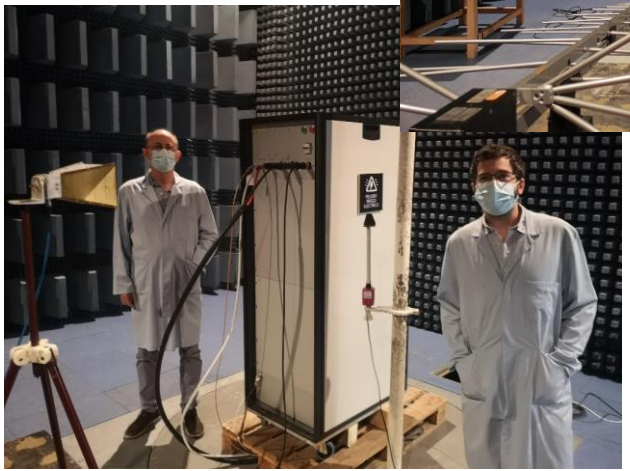
- Two CLIQ versions fully validated (**11 units manufactured)**
- Industrialization of CLIQv2 units

- **Conceptual Design Review –** Apr 2020
- **Production Readiness Review** – Dec 2021



Accomplished milestones

- **Reliability run with CLIQv2 units**
  (>8000 cycles of charge/discharge in nominal conditions)



- **CE marking studies of CLIQv2**
  - Core system of CLIQv1, v2 and v3 is the same, so previous prototypes, already in SM18 and Fermilab are considered reliable and safe
  - CE marking will be eventually repeated on the CLIQv3 units

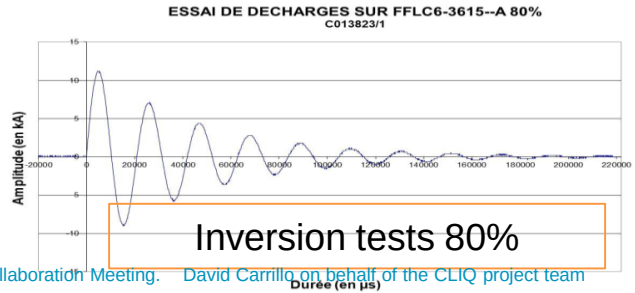
Accomplished milestones.
Qualification and production of of CLIQ capacitors

- **Capacitors for the String already delivered (Q1 2022)**

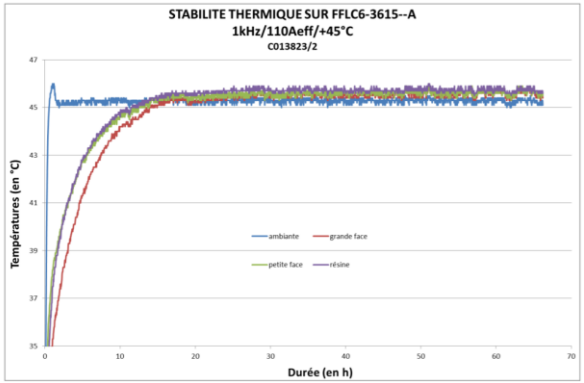
Endurance tests

Self-healing tests

Thermal stability test



Inversion tests 80%



Accomplished milestones.
Spurious triggering detection

- New budget time requirements for the interlock in case of a CLIQ spurious triggering * called for a campaign on the CLIQ current sensors immunity tests

  *see presentation by C. Hernalsteens & D. Wollmann about the criticality of fast failures (Wed 16h30)

- Fast transients (up to 5 kV) applied by capacitive coupling to the monitoring and power cables

- Present baseline sensors (main current transformer from Schneider and branch current transformers from N.Talema) found sufficient to detect a spurious trigger with the new requirements

- Nevertheless, two Rogowski coils have been added (negligible delay and cost impact) in order to have a complementary method detection, and also faster in case of future change of requirements

Accomplished milestones

- Qualification of CLIQv3 prototype finished in 2022
- Worldwide shortage of electronics forced the re-design of most of the CLIQ boards during 2022


CLIQv3 prototype qualification

CLIQv3 prototype

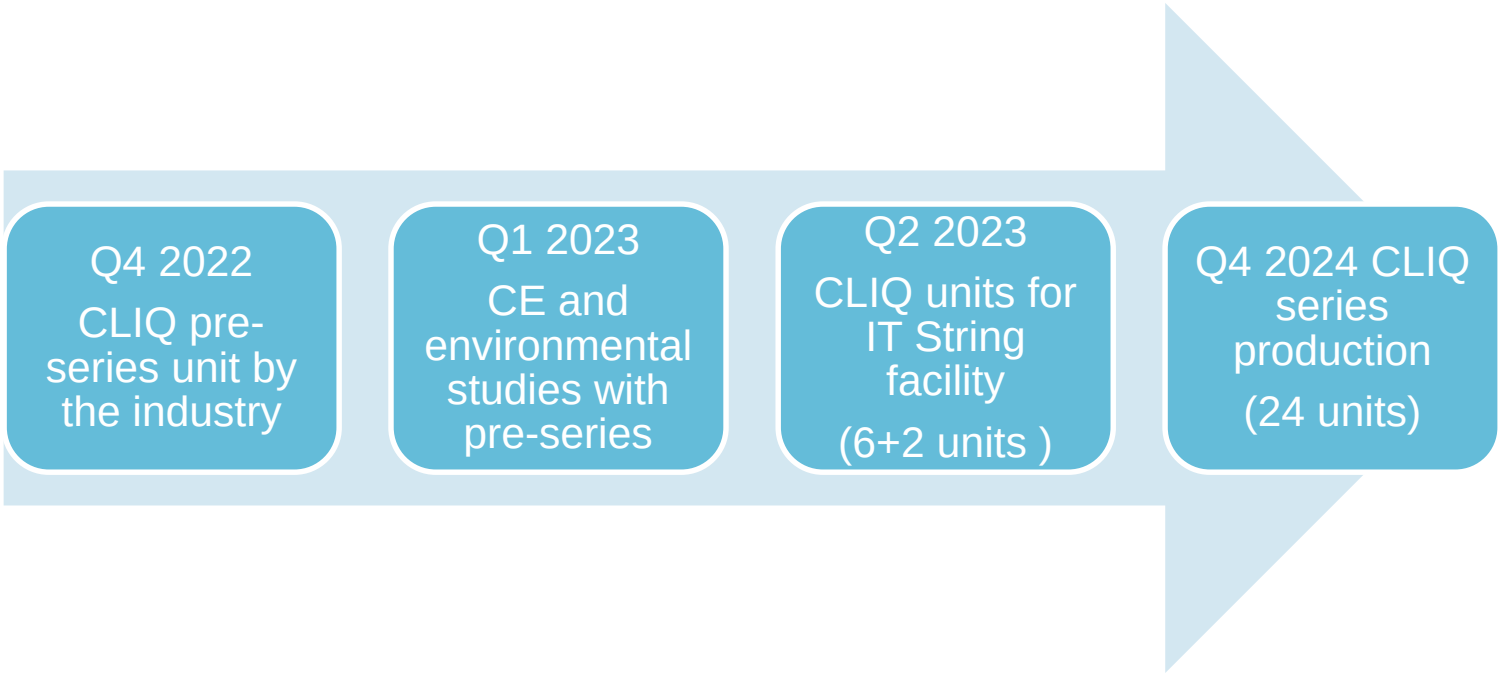
Ongoing activities

- CLIQ pre-series unit being assembled
- Green light given for their pre-series production of the recently re-designed CLIQ boards
- Control & monitoring boards firmware development


CLIQ pre-series unit assembly

One of the CLIQ control boards re-designed due to the shortage of components

Next steps


Q4 2022
CLIQ pre-series unit by the industry
Q1 2023
CE and environmental studies with pre-series
Q2 2023
CLIQ units for IT String facility
(6+2 units)
Q4 2024 CLIQ series production
(24 units)

CONCLUSIONS

- CLIQ machine version prototype fully qualified
- Dependability studies validated by the reliability run (more than 8000 discharges)
- CE marking studies (including safety assessment) for CLIQv2, CLIQv3 immunity tests performed
- CLIQ Machine version (v3) pre-series being assembled
- CE marking and CLIQ String production expected in Q2 2023 (as long as a all components are delivered according to present information from suppliers)

Thank you very much for your attention