Design and Manufacturing of the First Industrial-Grade CLIQ Units for the Protection of Superconducting Magnets for the High-Luminosity LHC Project at CERN

Felix RODRIGUEZ MATEOS , Stavroula BALAMPEKOU, David CARRILLO, Knud DAHLERUP-PETERSEN, Mathieu FAVRE, Joaquim MOURAO, and Bozhidar PANEV

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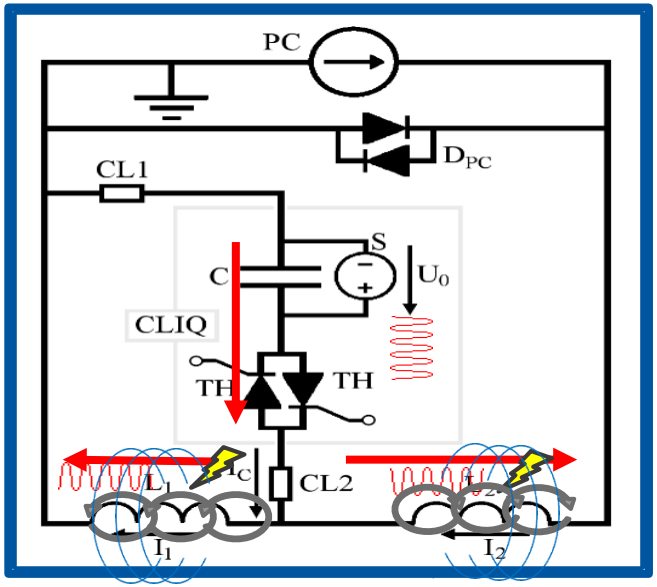
Introduction

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



Current change

Magnetic field change

Coupling losses (Heat)

Temperature rise

QUENCH

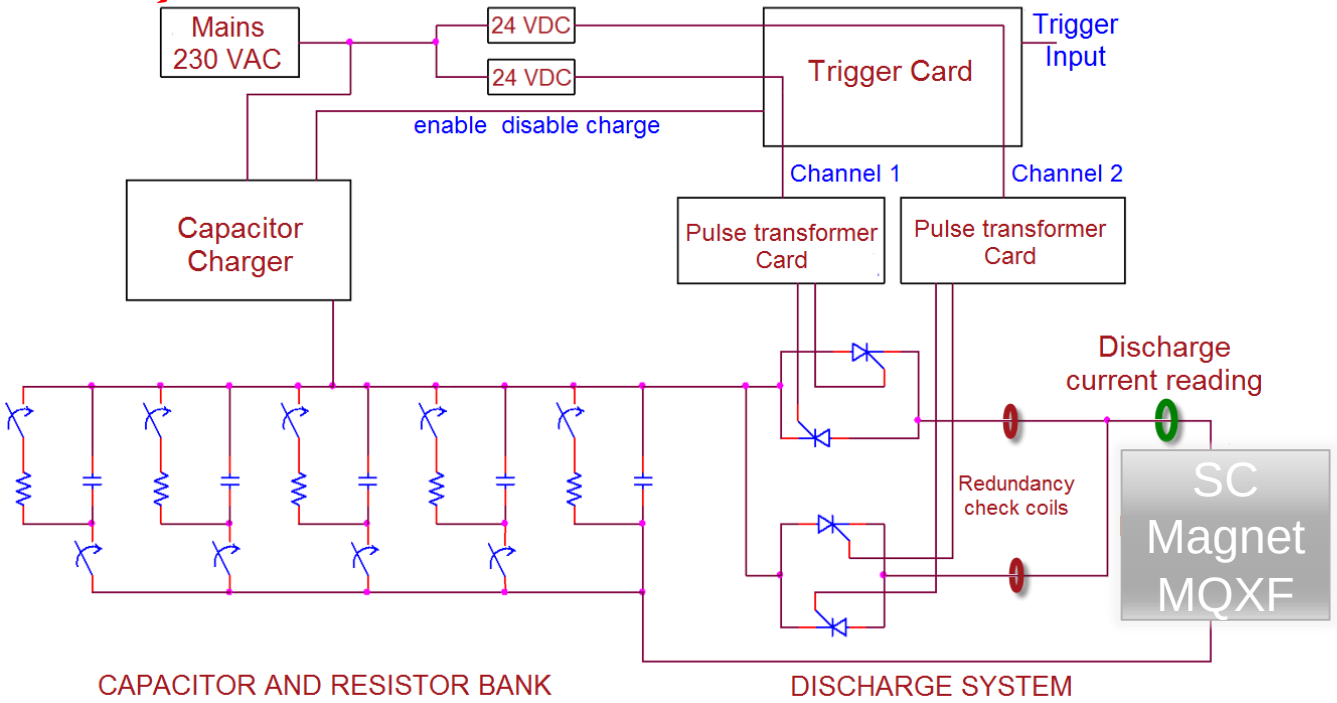
Courtesy Emmanuele Ravaioli

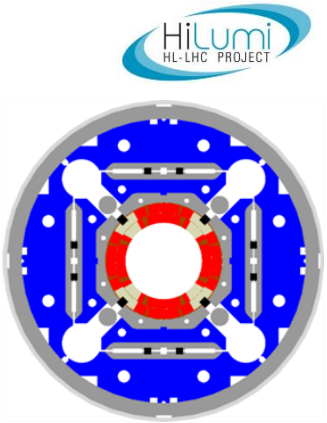
Introduction

- It will be used in the HL-LHC as a complement of the Quench Heater systems
- Two different prototype versions of CLIQ have been manufactured at CERN

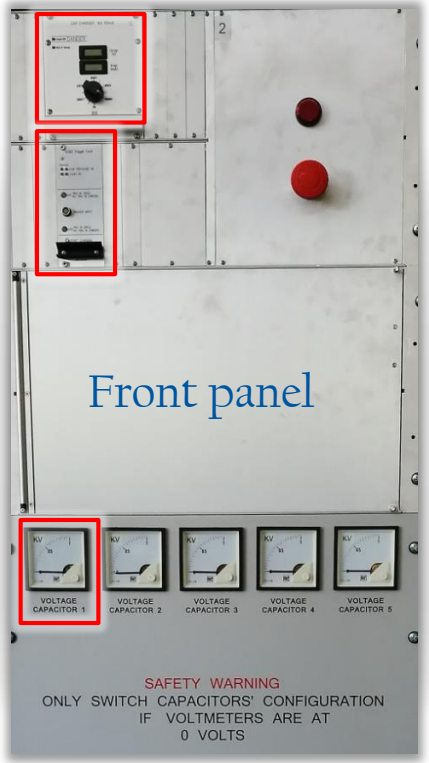
How to create the capacitive discharge?

Layout of the CLIQ unit



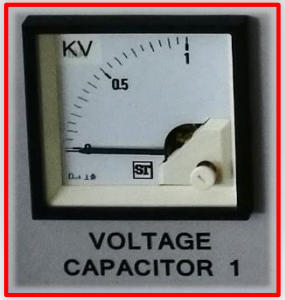


User interface



Capacitor charger panel

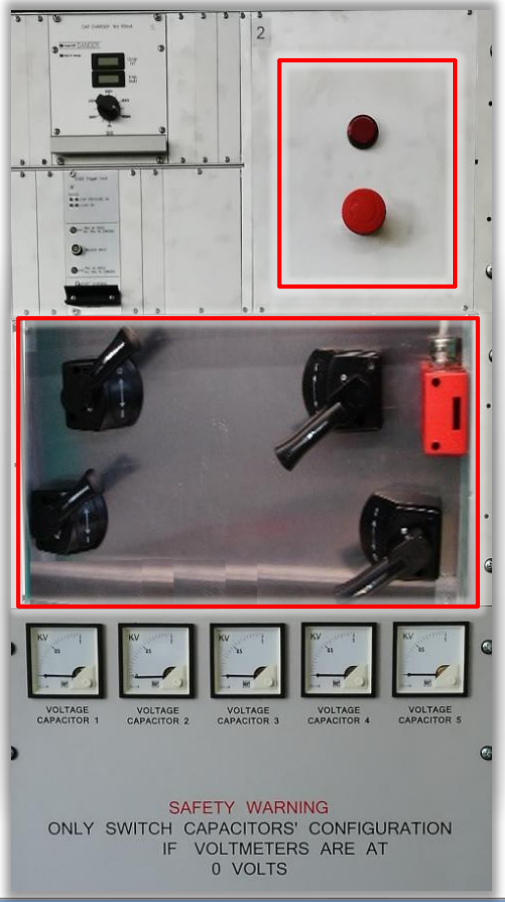
Trigger card panel



Safety first

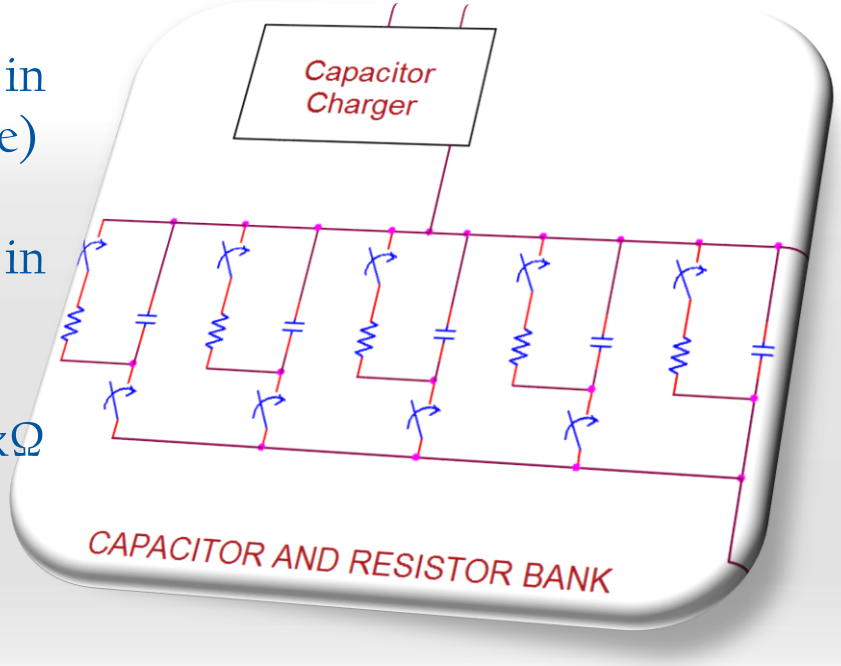
- Equipment stop button stop, mains current breaker, on/off switch
- Interlock triggers when user opens the door for capacitance selection
- Padlocks on the capacitance selectors

  -› **The stored energy is dissipated in the resistor bank**



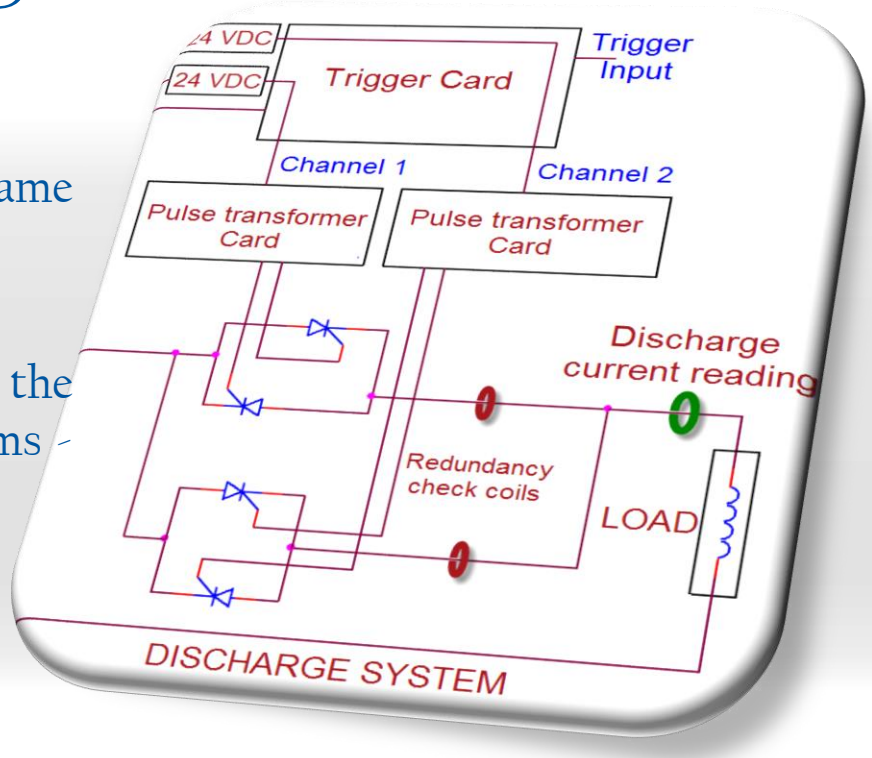
Energy storage circuit

- **Capacitor Bank:** 5x10 mF, 1000 V capacitors in parallel (dry, bipolar, metallized polypropylene)
- **Charger**: 100 mA charging current, 1000 V in ~ 8 min for 50 mF
- Resistor bank: 40 resistors, 100 W, 1 kΩ (R_{eq}=400 Ω)
- 24 VDC relays

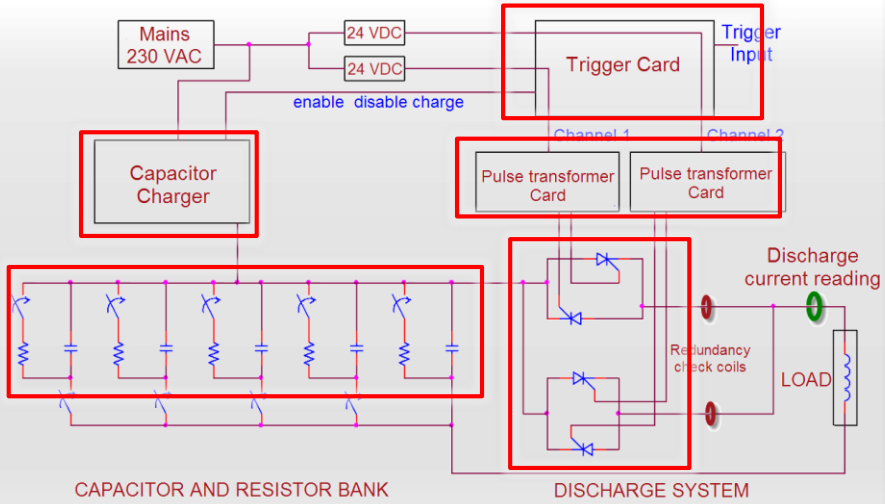


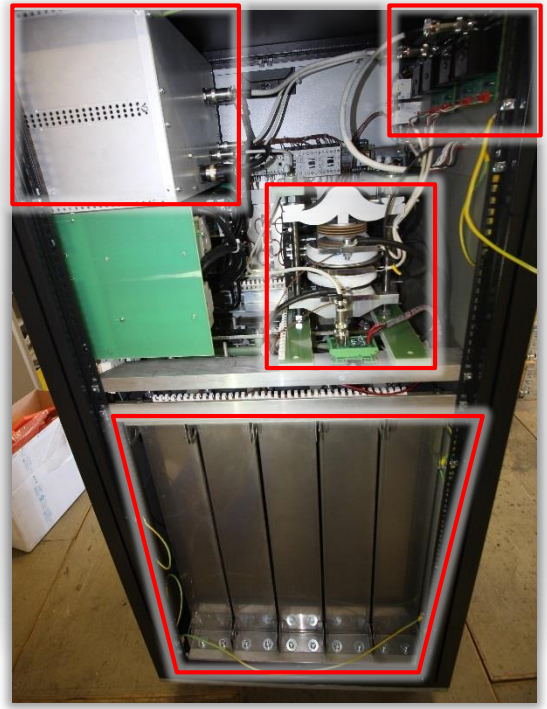
Trigger and discharge circuit

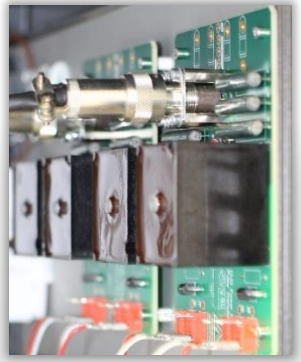
- Two 24 VDC power supplies
- Two trigger circuit generators (on the same board)
- Two pulse transformers boards
- The user (i.e. Quench Detectors) starts the trigger by opening a current loop -> 500 ms - 10 kHz pulse train
- Two Bi-directional Controlled Thyristors

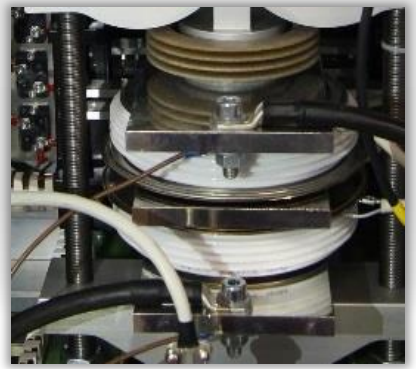


A glimpse into the CLIQ unit



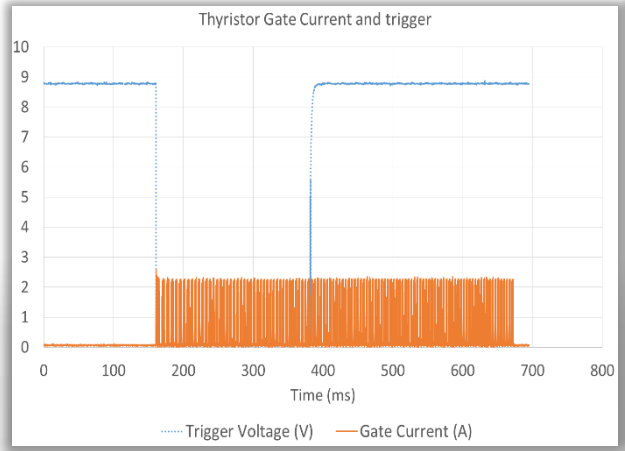


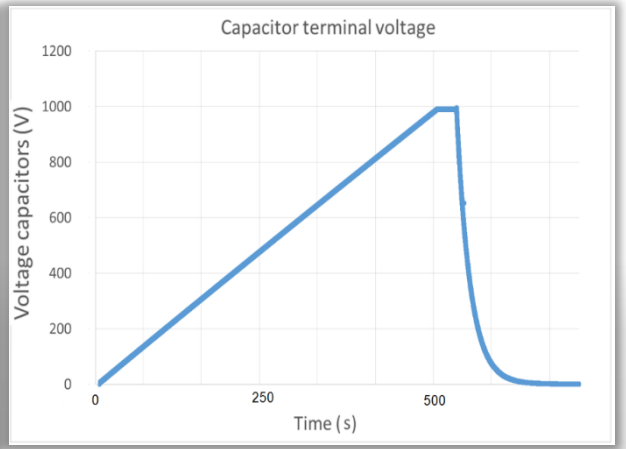


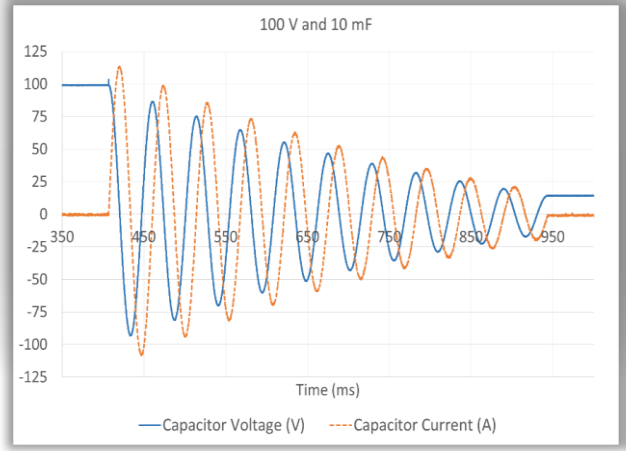


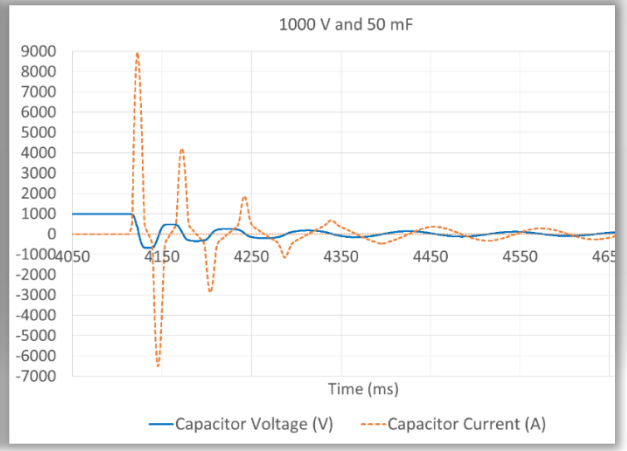
Individual System Tests

- Warm 7 mH load
- Hi-pot 2 kV
- Thyristors performance
- Power shutdown
- Discharge 100 V to 1000 V
- Visual displays









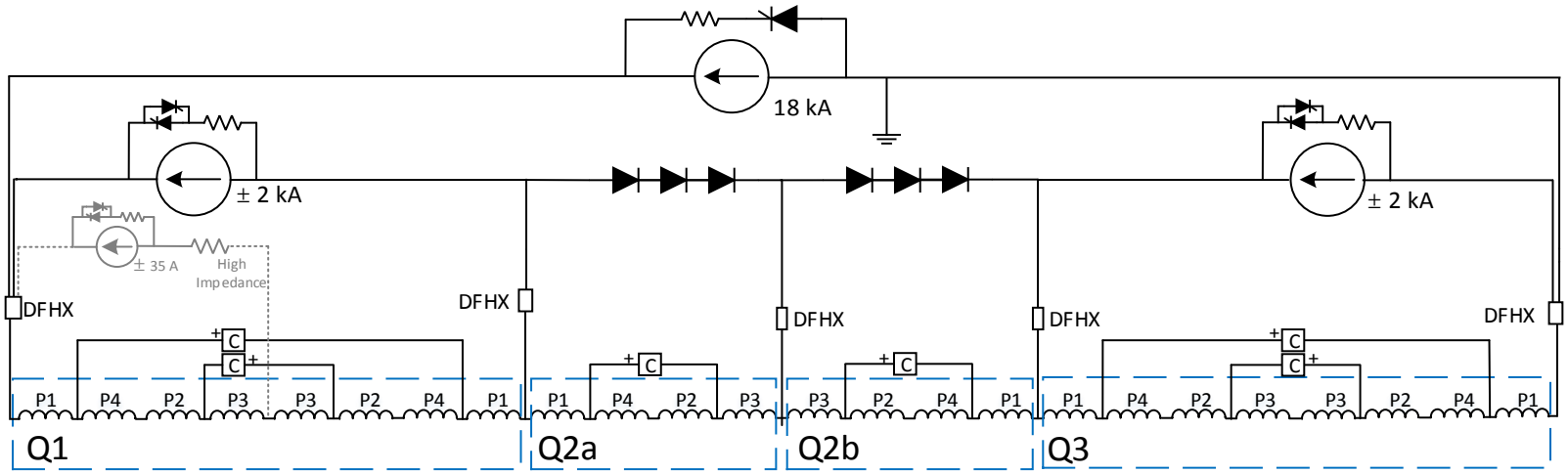
Conclusions

- The CLIQ v2 units are on the starting block to be used in an extensive R&D program at the test facilities at CERN on superconducting magnets also for the HL- LHC program

- A further optimization of parameters and the unit is expected in the following months -> CLIQ v3

Conclusions

- CLIQ v3 is intended to protect the LHC inner triplet magnets following their installation in 2024-25



Thank you for your attention

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