CERN

Proposal on a novel energy extraction system for superconducting magnet chains

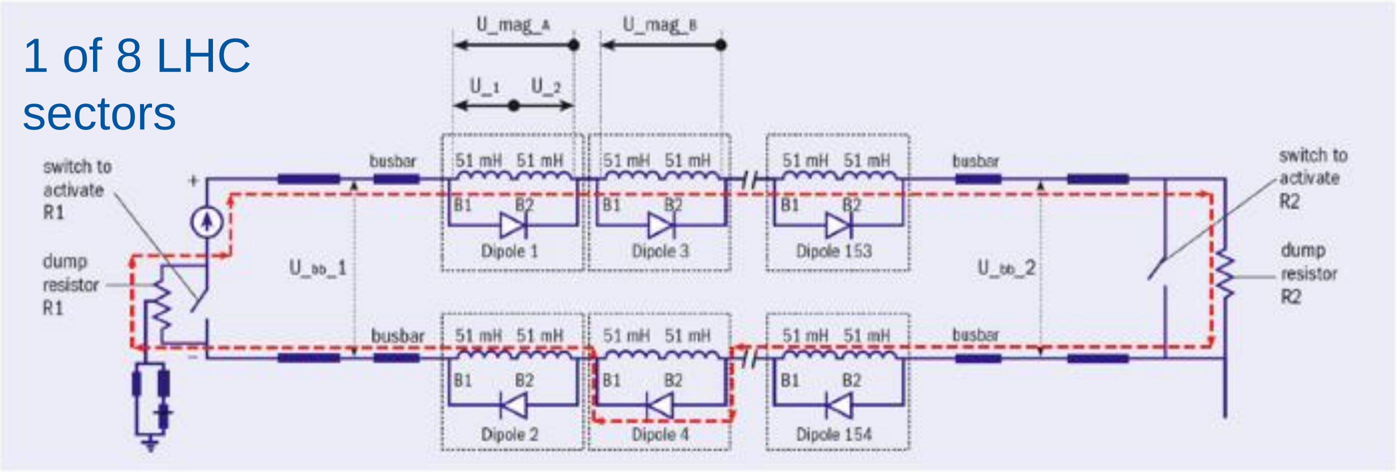
Energy Extraction for the FCC Era

Vasilios Dimitris Karaventzas
Felix Rodriguez Mateos

Need for energy extraction systems

- Superconducting magnets are used for generating high magnetic fields, 8.3 T dipole field for the LHC, 11 T for the HL-LHC dipole and 16 T predicted for the future colliders.
- Large magnetic systems with high inductance/current generating such high magnetic fields result in high stored energy.
- Superconductors under high magnetic field have increased risk of quench.

Energy Extraction as part of the magnet circuit protection scheme of LHC

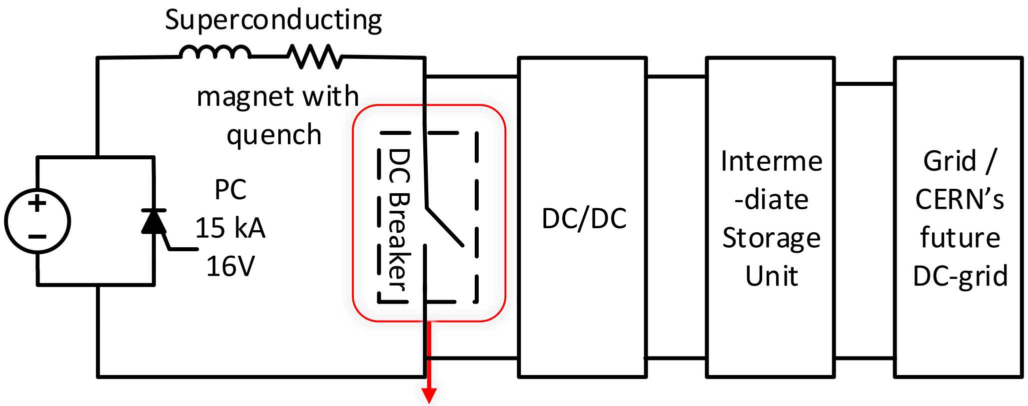


Per Sector:
- Inductance 15.7 H
- Nom I 11500 A
- Energy 1 GJ

QPS components:
- Quench Detection
- Quench Heaters
- Bypass diodes
- Energy Extraction

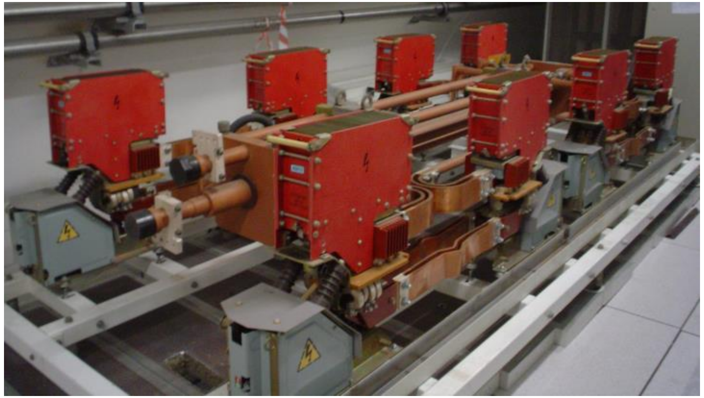
Courtesy of Andrzej Siemko, Safeguarding the superconducting magnets: CERN Courier - Aug 19, 2013

Concept for developing an active energy extraction system with energy recovery - 1



Protection system of multi-million CHF magnet chain requires a highly reliable operation:

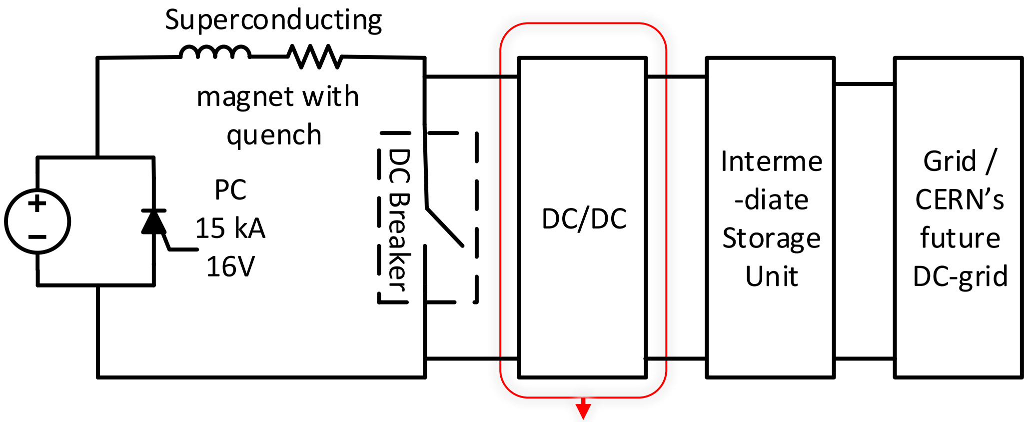
- Reliability study.
- Failure case study for malfunctioning of each stage of the extraction process.



- Knowledge accumulated within the TE Department.
- DC-breaker technology:
  - Electromechanical
  - Vacuum
  - Quenching superconductor
  - Semiconductor

The mechanical DC circuit breaker installed in LHC.

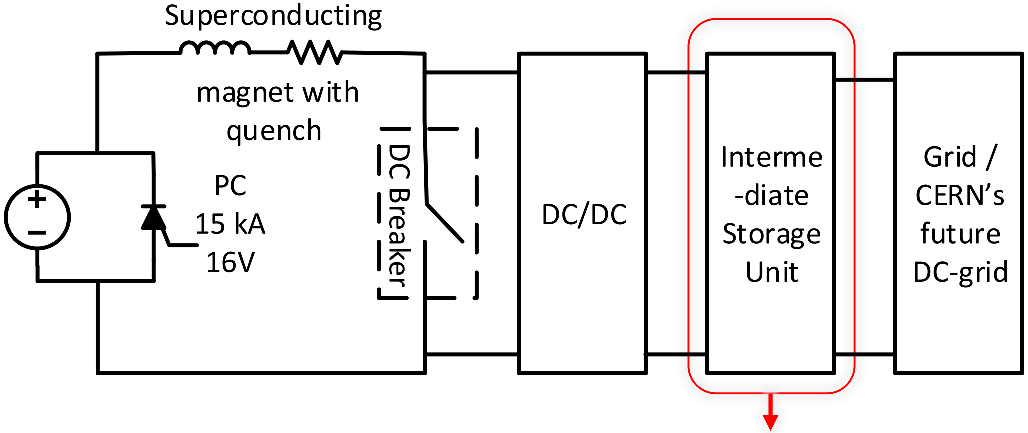
Concept for developing an active energy extraction system with energy recovery - 2



- The parameters of the converter depend on the properties of the superconducting magnets. Extraction voltage – Maximum current.
- "Pulse" type DC /DC converter.
- Need for a DC/DC converter that regulates its input voltage.
- Topology of the converter and accurate modeling of both switching and passive elements.
- Robust and responsive control scheme design.
- Scalability or modularity.
- Interconnection with the storage unit.

CERN's 13kA-18V LHC dipole converter.

Concept for developing an active energy extraction system with energy recovery - 3

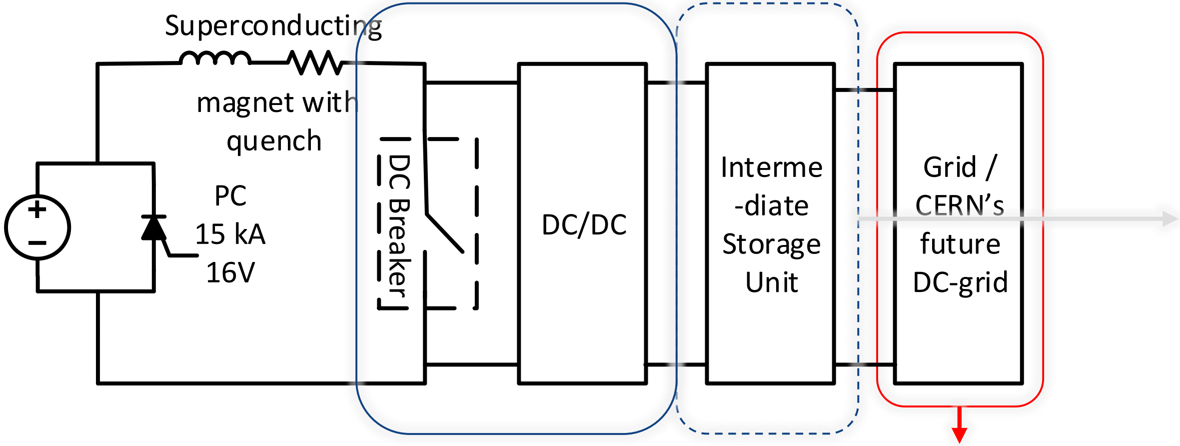


Capacitor bank used for the powering of PS.

- Study of possible storage devices, e.g. hybrid of capacitors, super capacitors, batteries etc.
- Feasible and economically viable solution.
- Storage management system design, adapted to the chosen storage system.

- Modular concept capable to cover the needs both of LHC and future accelerators.
- Important property, the rate of energy possible to be stored and discharged based on the requirements set by both the magnetic circuit and the DC-grid.

Concept for developing an active energy extraction system with energy recovery - 4

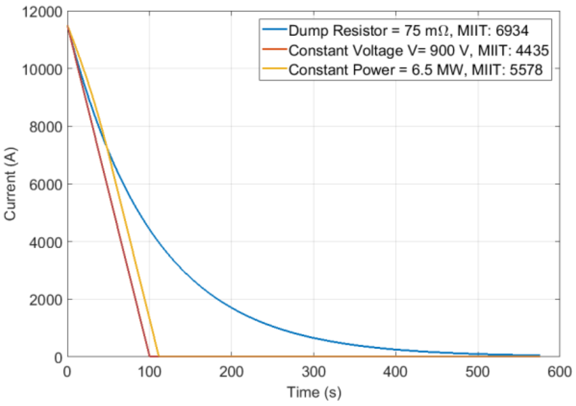


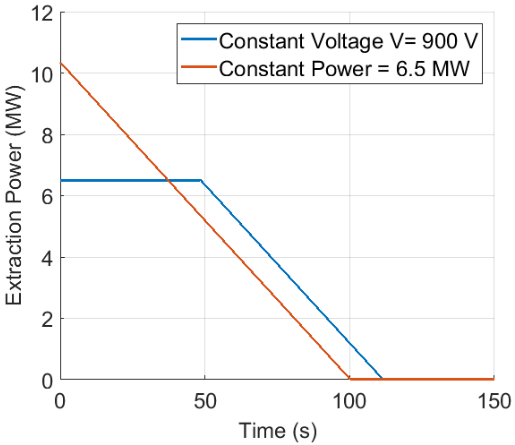
The main study:
The interface between the magnet circuits and the DC network.

- The energy will be restored to the grid or to an internal grid used for the next energy ramp.
- The sizing of the storage unit depends also on the rate at which the grid can absorb the energy.

- Advanced Power-Quality Technologies for Future Circular Collider (FCC) - Thomas Hohn, FCC Week 2018
- FCC Powering concepts - Francisco R. Blanquez, FCC Week 2018

Comparison between extraction systems





MIITS: A zero-dimensional concept to study hot spot temperature.

$$MIITs(t) = \int_0^t [I(t)]^2 dt$$

$$MIITs_{exp} \cong \frac{I_{max}^2 L_{tot}}{2RN_{EE}}$$

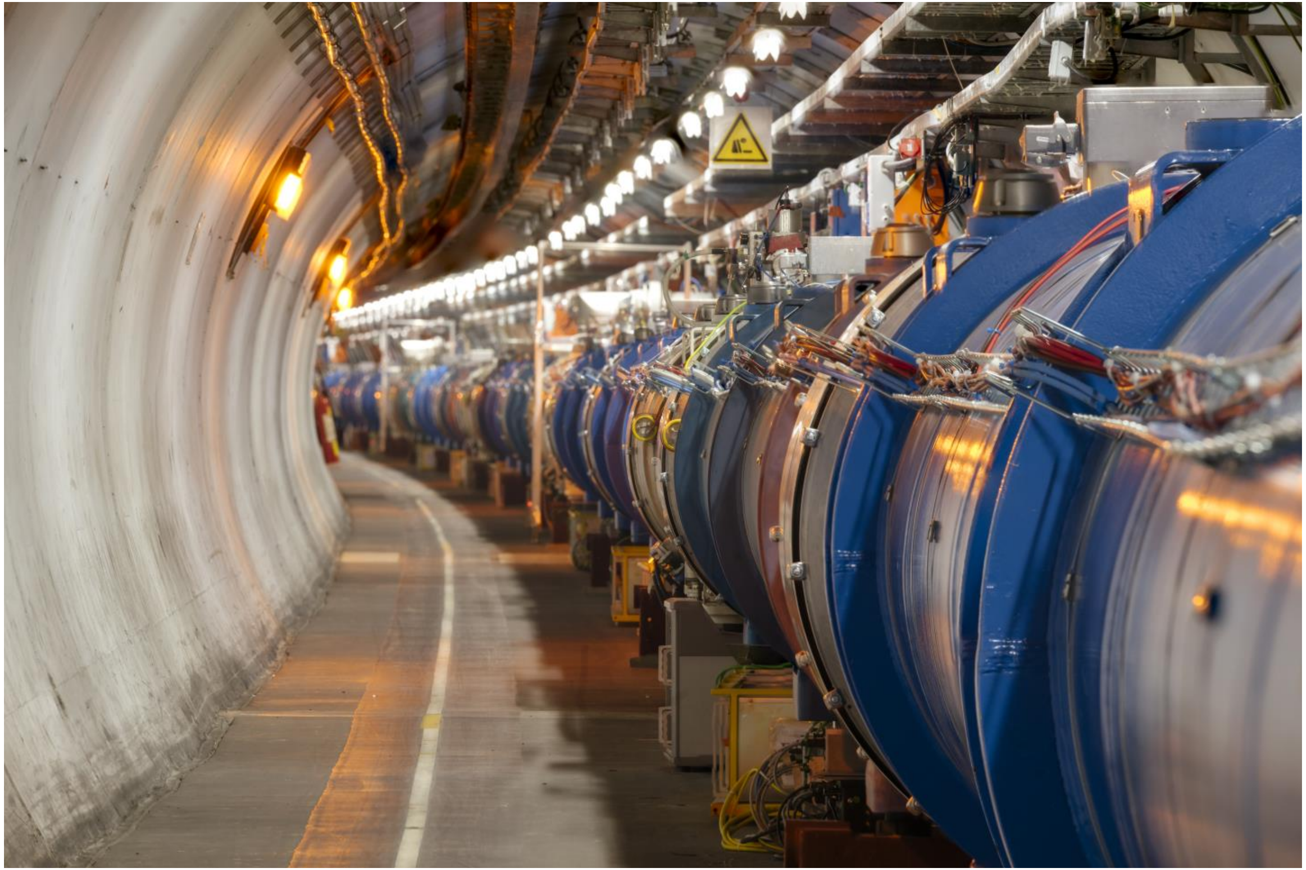
$$MIITs_{lin} = \frac{I_{max}^3 L_{tot}}{3N_{EE}V_{max}}$$

$$t_{0,lin} = \tau \quad - \quad t_{0,exp} \approx 5\tau$$

$$\boldsymbol{MIITs_{lin} = MIITs_{exp}} \Rightarrow \boldsymbol{L_{tot,lin} = \frac{3}{2} L_{tot,exp}}$$

Summary

1. One of the proposals today is the use of a DC grid to which different power converters of the magnet circuits will be connected – details of this are to be developed.
2. The key elements for designing the future FCC energy extraction system are:
   a) the design of the interface between the magnet circuits and the DC network.
      i. DC-breaker
      ii. DC/DC converter
      iii. Intermediate storage unit
   b) the design of the redundant classical system that will be necessary in case the DC network fails.
   c) the related control for the implementation of such an interface.
   d) a dependability analysis.
   e) the strategy to be applied in the different nominal scenarios and failure cases.
   f) impact onto the future collider's design.



Questions?

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