Avoiding Loss Of Beams In FCC Using Superconducting Magnetic Energy Storage (SMES)

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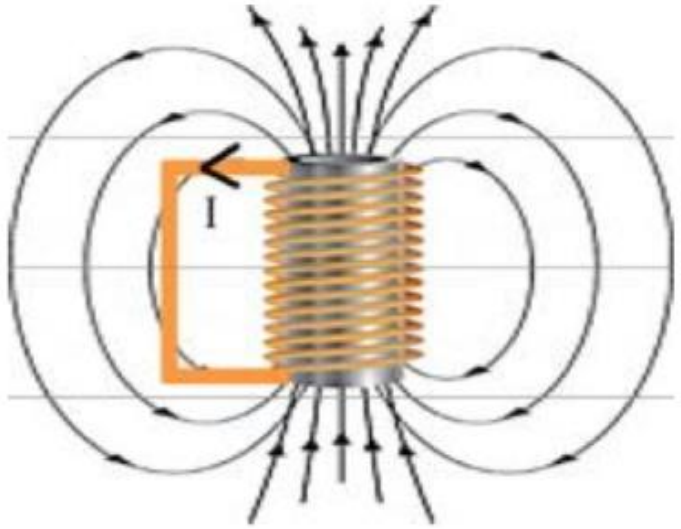
SMES:

Stores 10 – 100 MJ of energy in the magnetic field generated by a superconducting coil

Circulating current sustains the magnetic field

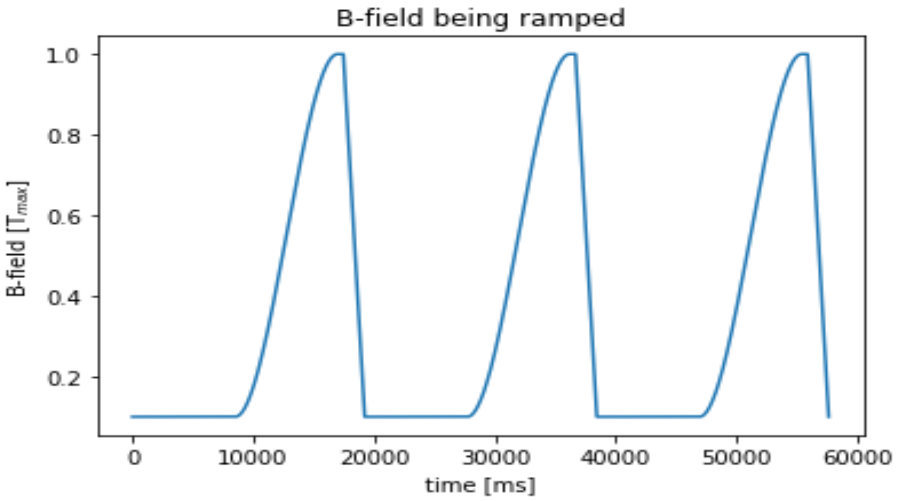
Superconductivity ensures infinitesimal resistive losses



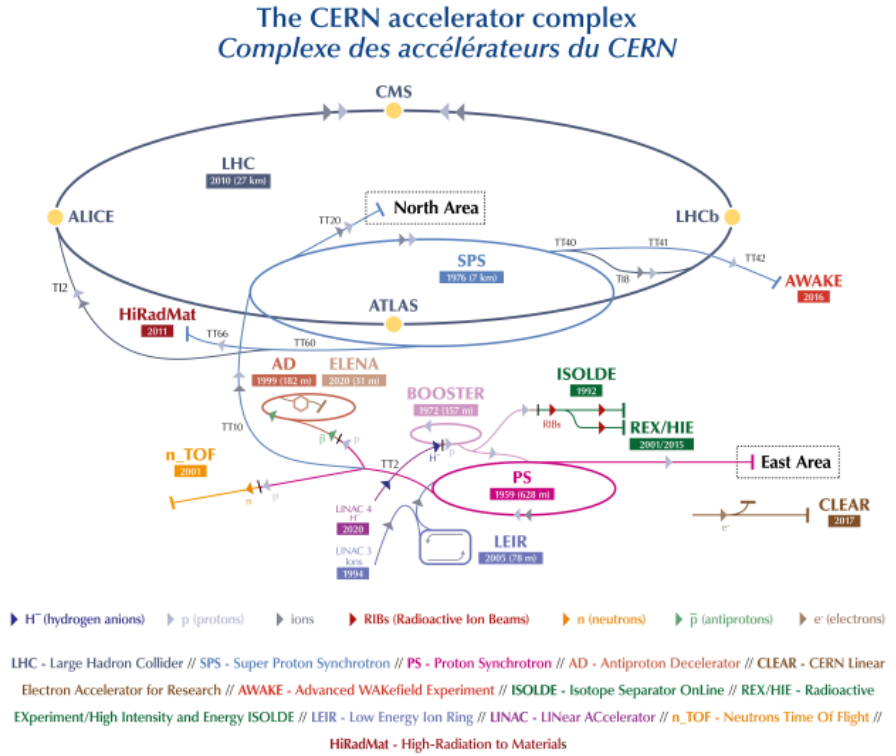
2 Modes of SMES operation

1: For Cyclic machine:

- Pulsed power extraction cause voltage variations on the regional grid
- Both PS and SPS operate in pulsed cycles
- PS uses large capacitor banks for intermediate energy storage.
- SPS uses a reactive filter which is not effective enough to avoid interfering with the regional grid. SMES has higher energy density and is safer than capacitors, SPS has liquid Helium, PS does not



The energy stored within the magnets at SPS is proportional to the square of their magnetic fields

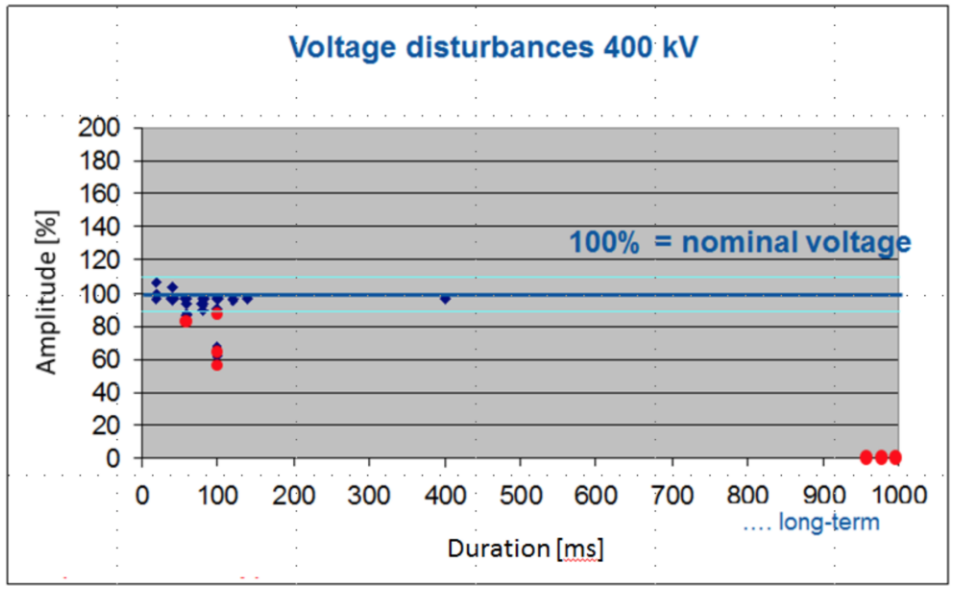


SMES = Intermediate energy storage between cycles

2 Modes of SMES operation

2: For colliders

- SMES Constantly on stand-by
- Supplies power during subsecond voltage dips in order to avoid loosing the beam



Ref: K. Kahle, "Power Converters and Power Quality". arXiv:1607.01556v1

- The LHC experience voltage dips (glitches)
- Typical time-scale: 10 - 1000 ms
- Current system sustains ≤ 20 ms glitches
- The LHC operates at 100 MW
- The cryogenics require 40 MW
- Consequence of > 20 ms glitches:
  Beam loss & hours of down time
- Consequence of > 300 ms glitches:
  Loss of cryogenic refrigeration = 24 h down time
- 100 MJ SMES to supply LHC with power during 1 second for > 20 ms glitches
- 40 MJ SMES to supply cryogenics with power during 1 second for > 300 ms glitches

FCC:

- Continuously colliding protons at constant energy
- Will presumably suffer similar voltage instability as LHC
- FCC power demand = 554 MW ≈ 5 times LHC power demand
- 554 MJ 554 MW SMES system on stand-by

- SPS is part of the LHC injector chain
- Will presumably serve the same purpose for FCC
- SPS operates at 19.2 s cycles
- Peak energy stored in SPS magnets = 110.4 MJ
- Ramp up = 8.4 s
- Ramp down = 1.7 s

Thank you for listening!

Some references:

SMES:
P. Tixador, "13 – Superconducting magnetic energy storage (SMES) systems" https://doi.org/10.1533/9780857097378.3.442

LHC:
K. Kahle, "Power Converters and Power Quality".
arXiv:1607.01556v1

SPS:
B. Lindstrom, "Criticality of fast failures in the high luminosity large hadron collider"
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