Progress with POPS

Jean-Paul Burnet
TE/EPC

IEFC workshop, Feb 2010

POPS What is it?

POPS will feed the PS main magnets.

It's a completely new power system.

It will replace the present powering system:

- Siemens motor-generator
- transformers and thyrsitor rectifiers
- control systems

Main difference: rotating machine versus static converter!

Why replacing the present power system?

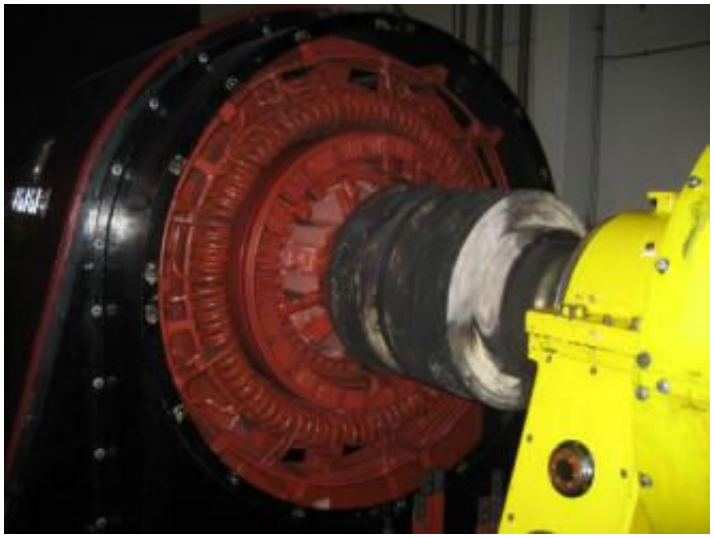
Single point of failure of the LHC injector chain!

Any fault on the rotating machine can lead to LHC stop for weeks!

- no spare rotors nor stators, see ATC/ABOC days 2007
- Ageing machine suffering of mechanical fatigue

Why replacing the present power system?

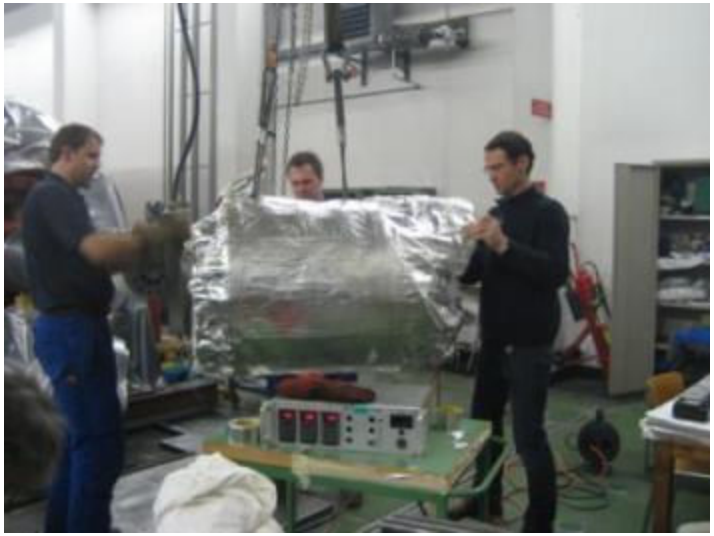
A human error can also generate many weeks of repair.



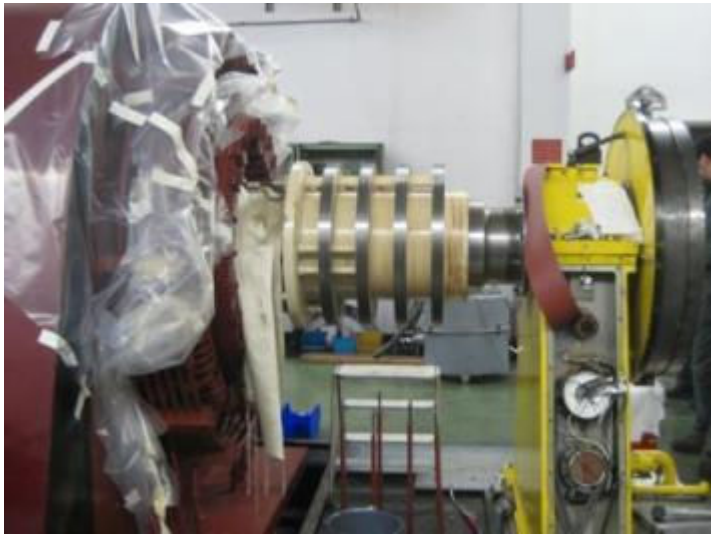
Just forget to put back the motor brushes and you create 10 kA short-circuit and arcs on the collector.

We needed three weeks to repair with the help of Siemens.

Example of repair, 2010

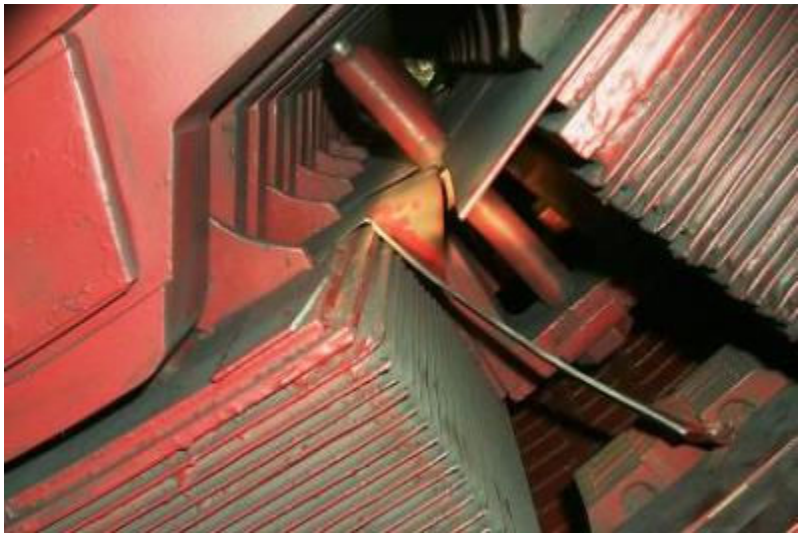


Example of repair, 2010



Example of repair, 2006

Broken fan blade



Failure of the spare rotor (insulation)

Present situation regarding spares

Lot of components are available as spares.

But only the 13MVA transformer can replace the rotating machine in degraded-mode.

LHC Cycle can be done in 6s (instead of 3.6s)

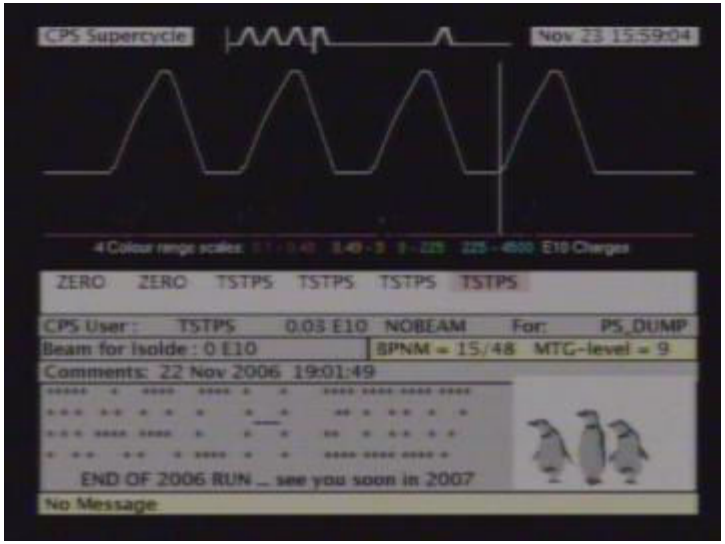
Only 4 cycles / minute can be done (instead of 16)

LHC program can be done with the 13MVA but nothing else.

We ran the PS for the AMS tests (February 2010) with the 13MVA transformer.

26 GeV/c tested in 2006 without beam

26 GeV/c tested with beam in 2009



POPS Planning

Contract signed on December, 17th 2007 with Converteam

Original planning

January – December 08:	Design CVT & CERN
December 08 – April 09:	Civil engineering works
June 09:	First delivery from Converteam
June – September 09:	Installation CVT
October 09:	Commissioning
November – December 09:	First test with PS machine
March 2010:	POPS in operation

Since we have no shut down in 2010

January 2010 – April 2010:	Commissioning on dummy load 10 SPS magnets (MBE) 0.1H instead of 1H, at full current (6kA)
March 2011 ?	Test on PS magnets
April 2011 ?	POPS in operation

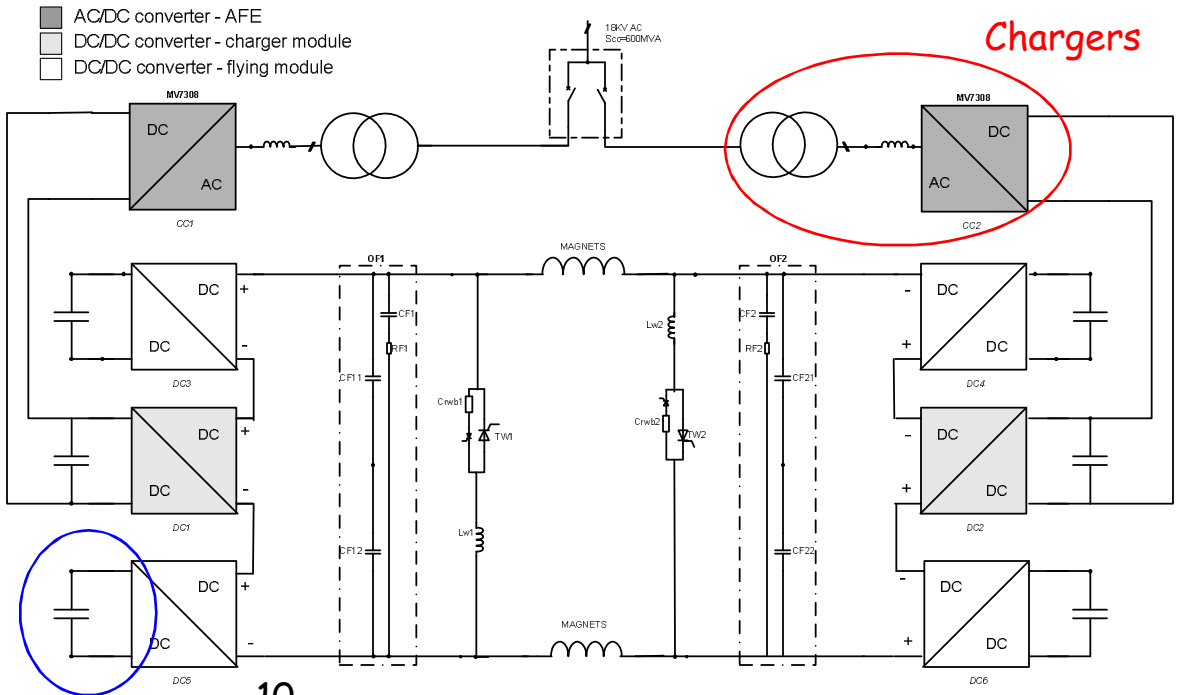
POPS: Power system based on capacitive storage

The energy to be transferred to the magnets is stored in capacitors

- DC/DC converters transfer the power from the storage capacitors to the magnets.
- Four flying capacitors banks are not connected directly to the mains. They are charged via the magnets
- Only two AC/DC converters (called chargers) are connected to the mains and supply the losses of the system.

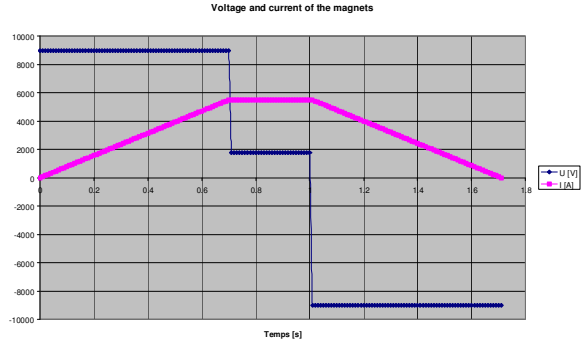
- Classical polypropylene dry capacitors 2mF/5kV, 126 cans (80kg) per bank
- Six outdoor containers, 18 tons, 40 feet (total value 1.48F)
- Medium Voltage Drives
- Turnkey system
-
- Main losses:
  - 180kW in air
  - 600kW water cooled

Patent
The global system with dedicated control has been filed as a patent application. European Patent Office, Appl. Nr: 06012385.8 (CERN & EPFL)

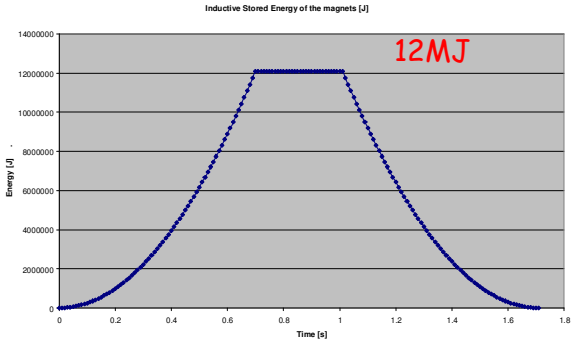


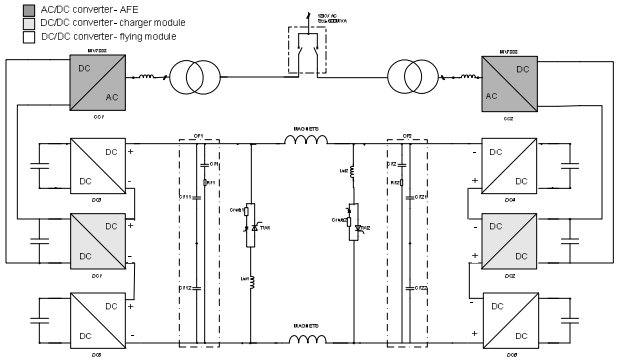
POPS basic principle

Magnets current and voltage

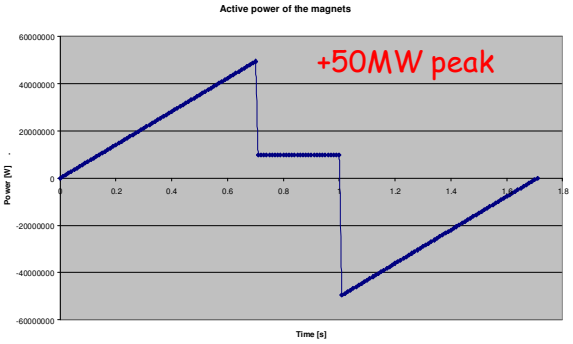


Stored magnetic energy

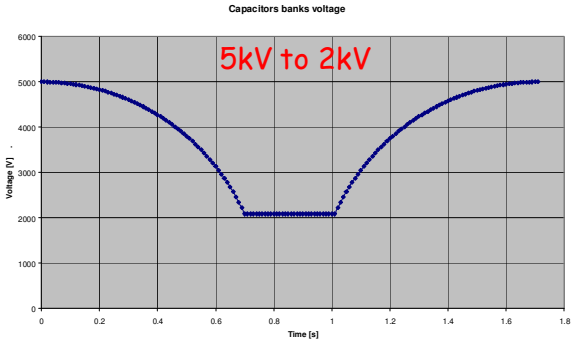




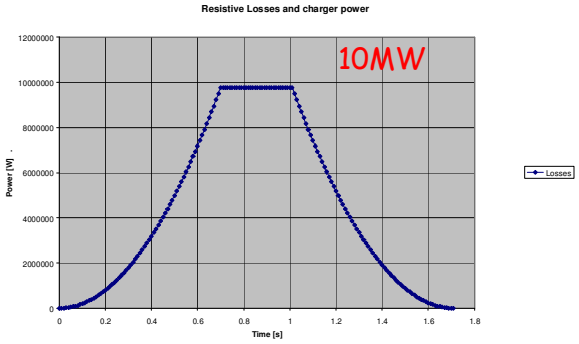
Power to the magnets



Capacitor banks voltage



Power from the mains



POPS numbers

POPS required:

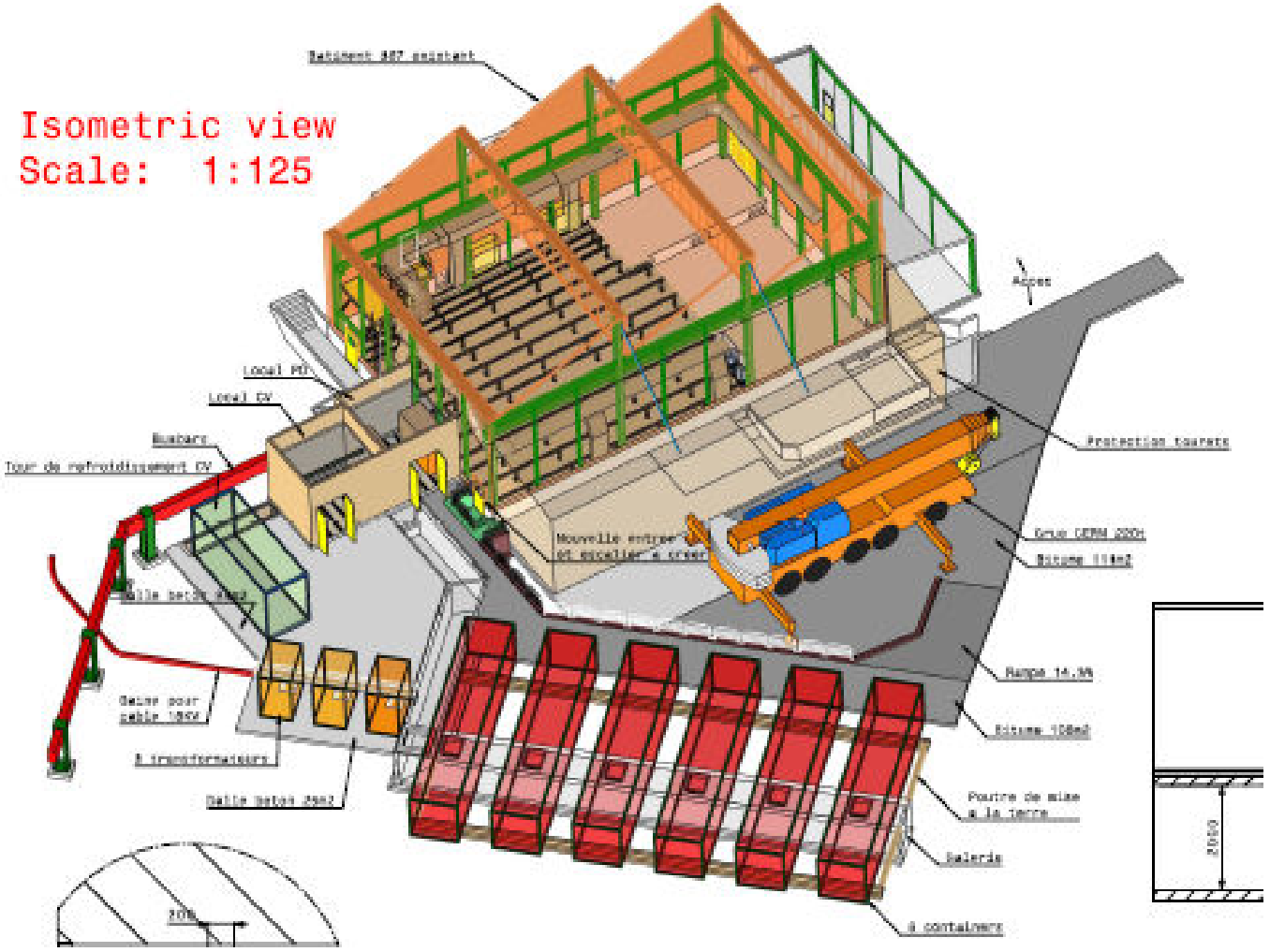
- 600 kW cooling tower
- 170 kW air-conditioning
- 200 m^2 indoor
- 800 m^2 outdoor
- 10 MVA on the 18kV network (3 switch-gears)
- 700 kVA on the 400V network

POPS budget:

Converteam: 9.23 M€ + 1.05 M€
(spares & maintenance for 5 years)

Infrastructure: 3 MCHF + …
(25% civil engineering, 30% cooling ventilation, 17% electricity)

POPS outdoor layout



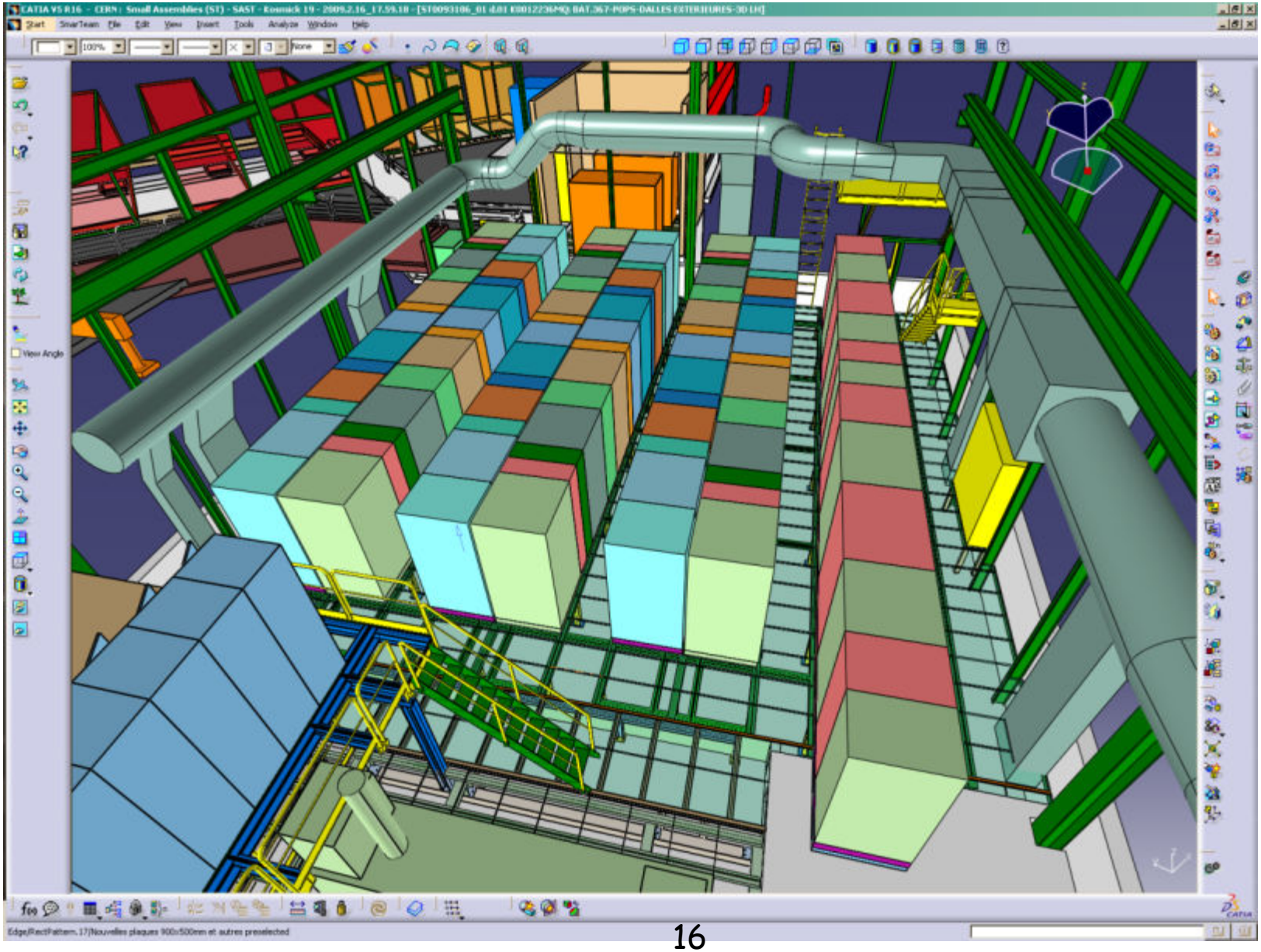
End of the construction

Outdoor

End of the construction

Outdoor

POPS indoor layout



End of the construction

Indoor

POPS infrastructure

During the infrastructure works, we discovered progressively that the building needed an upgrade:

- New fire detection
- New walk ways close to the ceiling to access the lightning & fire detection
- New lighting system
- New platform for crane maintenance
- New AUG chain
- New smoke extraction
- ….




Last discovery: the roof has to be “consolidated”.
GS will take care of it, 500kCHF!

POPS water cooling system

POPS required a water cooled circuit of 600 kW
EN/CV installed a dedicated cooling tower

Cooling pipes completed, X-ray tested
Water cooling system is now operational

POPS ventilation

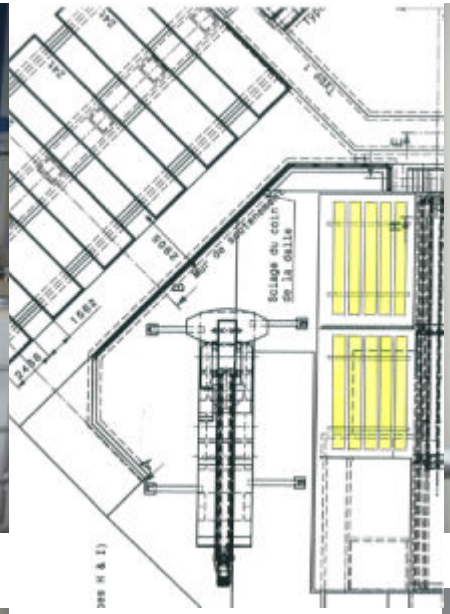
POPS required 170 kW of air conditioning

Ventilation system is operational

For both systems, it is impossible to commission at full load without the PS magnets.

POPS dummy load

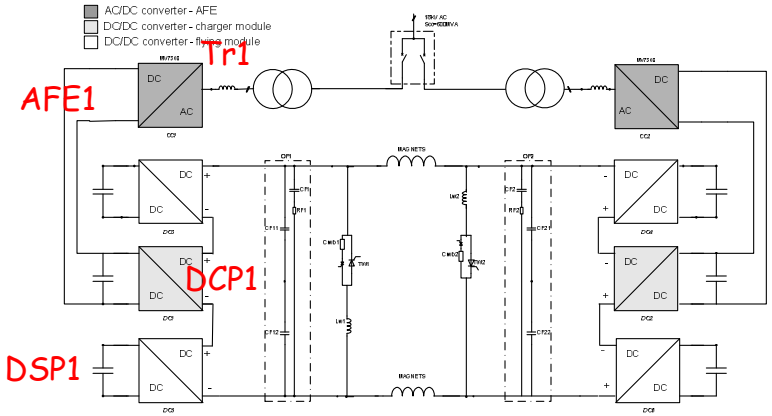
TE/ABT hangar has been transformed as a magnet test bench



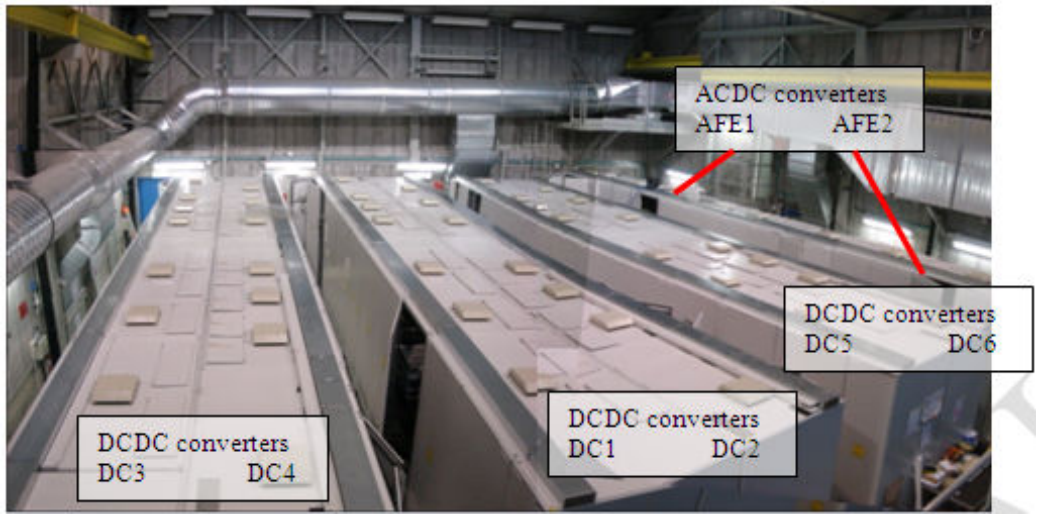
10 SPS magnets (MBE)
5kA peak
10 mH

POPS commissioning

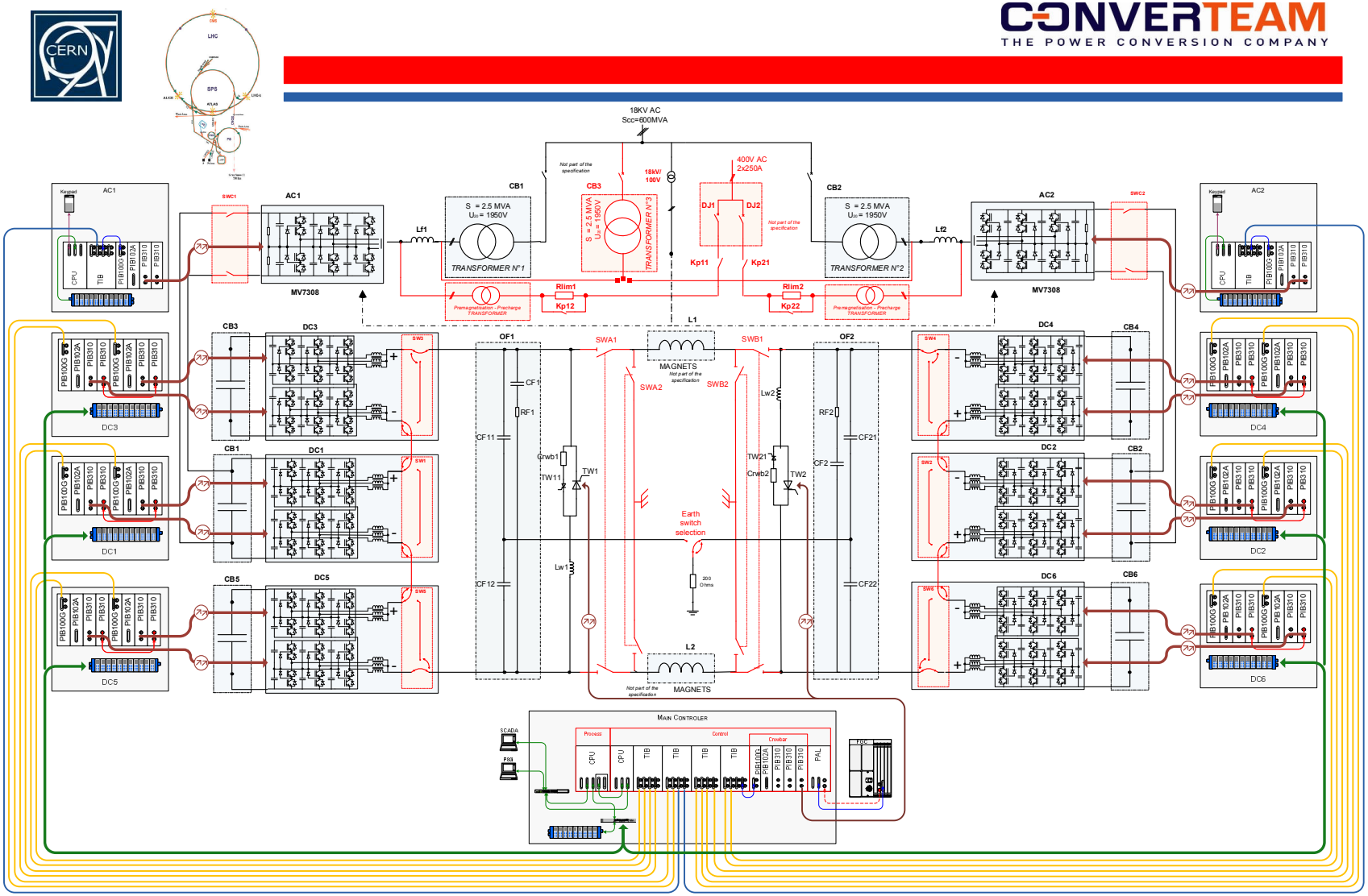
All converters installed.
All cooling units filled up and running.
All power cables tested.
All auxiliaries tested.



Power tests started beginning of January 2010
The commissioning will be done on a dummy load
Peak current: 6kA (to be negotiated with MSC)
Rms current: 1kA
1/10 of the nominal energy (1.25MJ/1.8MJ instead of 12MJ)

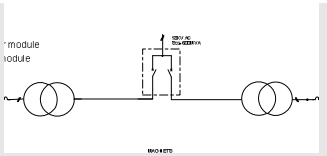


POPS electrical schematic



POPS commissioning

First, the power transformers (2.5MVA)

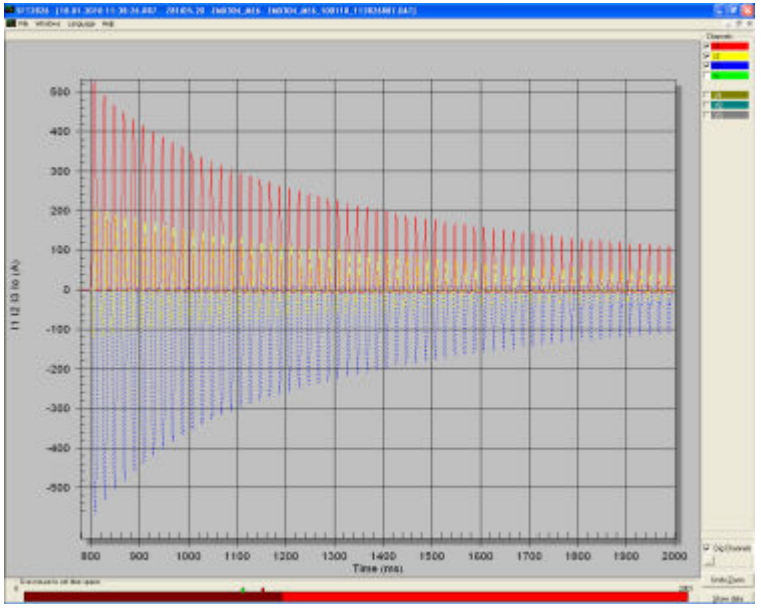


Sepam software tested successfully.

Power cables tested, Auxiliaries tested.

Tr1 and Tr2 tested at no load.
Maximum Inrush observed 7.5*In

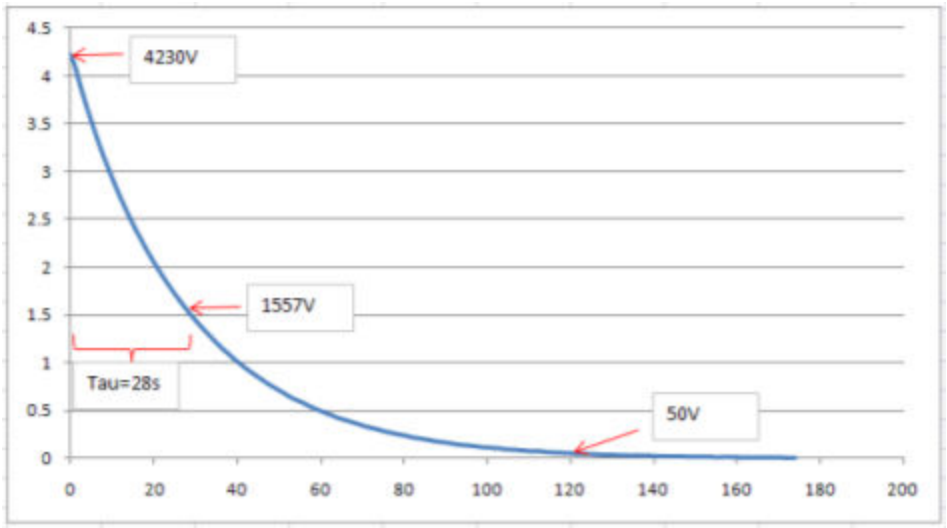
Still to be done:
Heat run (impossible without the load!)
New transformer Roofs to be installed due to leakages



POPS commissioning

Test of the capacitor banks individually

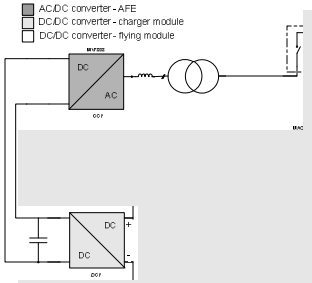
Capacitor charged up to 4.2kV with an external power supply
Discharged through the 96 ohm resistance.
Max resistor ΔT 140°C

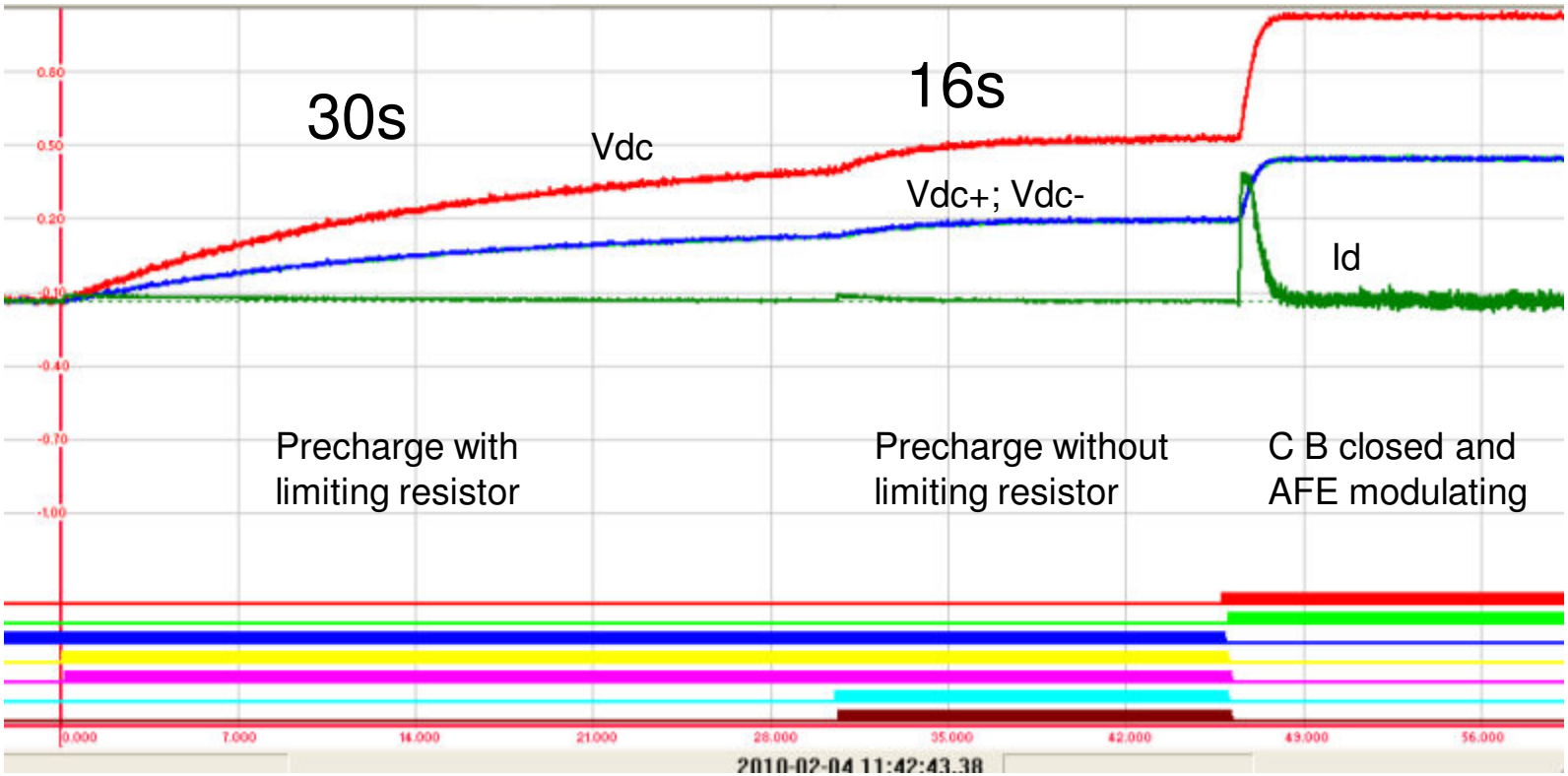


POPS commissioning

Test of AFE with a capacitor bank

Power up procedure completed on AFE2 + DCP2 + DSP2
Tests done last week

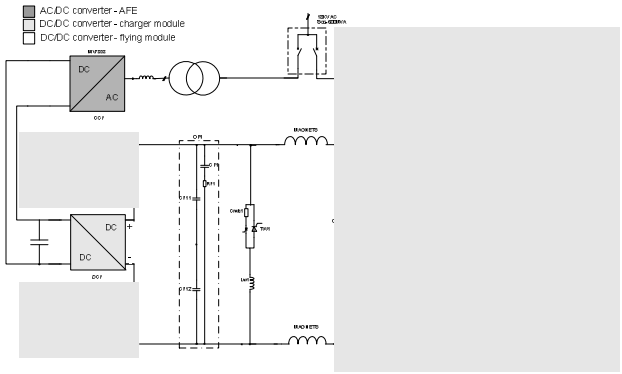




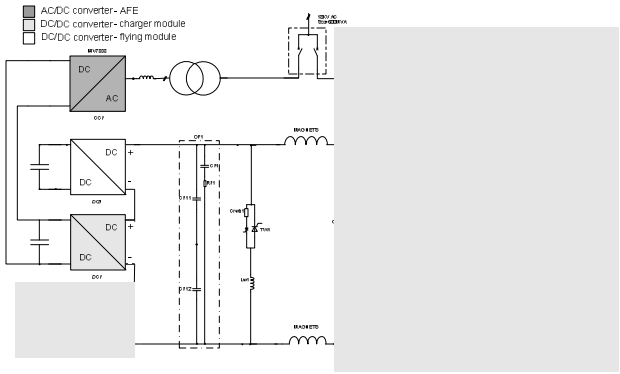
POPS commissioning

Next steps

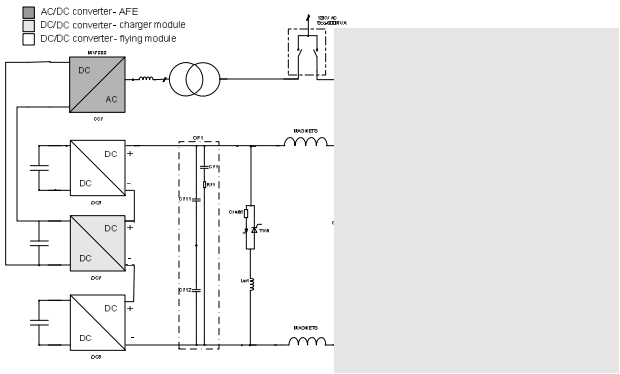
Power up AFE1 + DCDC1 + DSP1 + magnets
Planned week 7 - 8



Power up AFE1 + DCP1+ DSP1 + DCP3 + DSP3 + magnets
Planned week 9



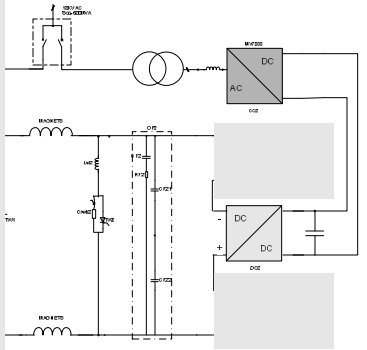
Power up AFE1 + DCP1+ DSP1 + DCP3 + DSP3 + DCP5 + DSP5 + magnets
Planned week 10



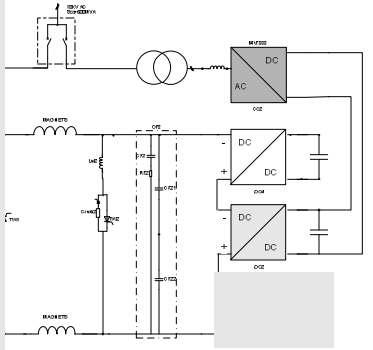
POPS commissioning

Next steps

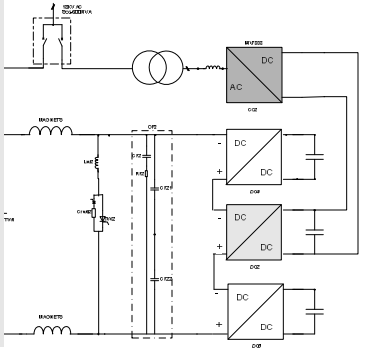
Power up AFE2 + DCDC2 + DSP2 + magnets
Planned week 11



Power up AFE2 + DCP2+ DSP2 + DCP4 + DSP4 + magnets
Planned week 12



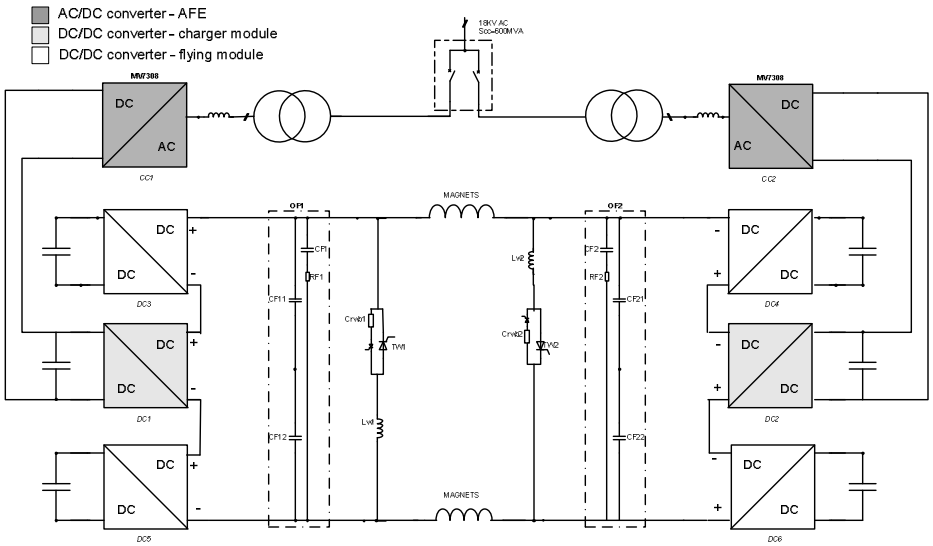
Power up AFE2 + DCP2+ DSP2 + DCP4 + DSP4 + DCP6 + DSP6 + magnets
Planned week 13



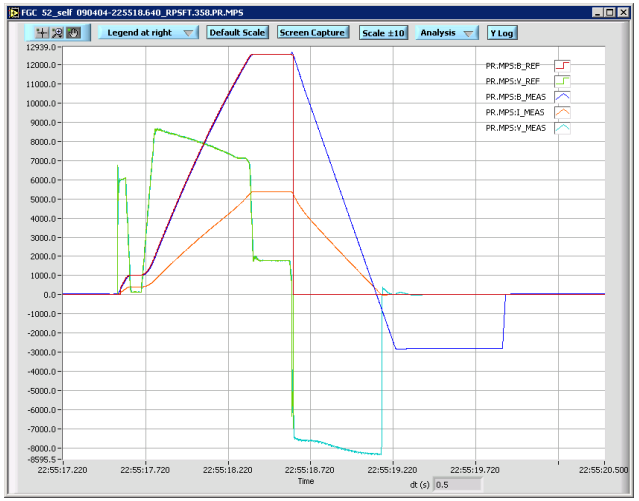
POPS commissioning

Final steps

Full power test: week 14 (10 April)



Final reception tests:
planned week 14



POPS control

POPS will be controlled by a FGC as now for the MPS.

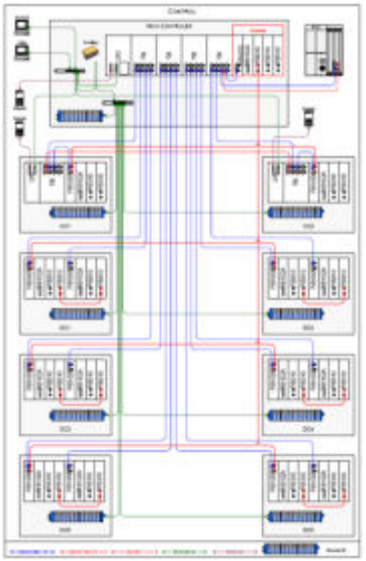
For the cmd & status, EN/ICE will provide a HMI done with PVSS.

CCC will have to use both system.

Bloop as today.

Postmortem with FGC.

CVT will change the optic fiber cable (too fragile) after the final tests

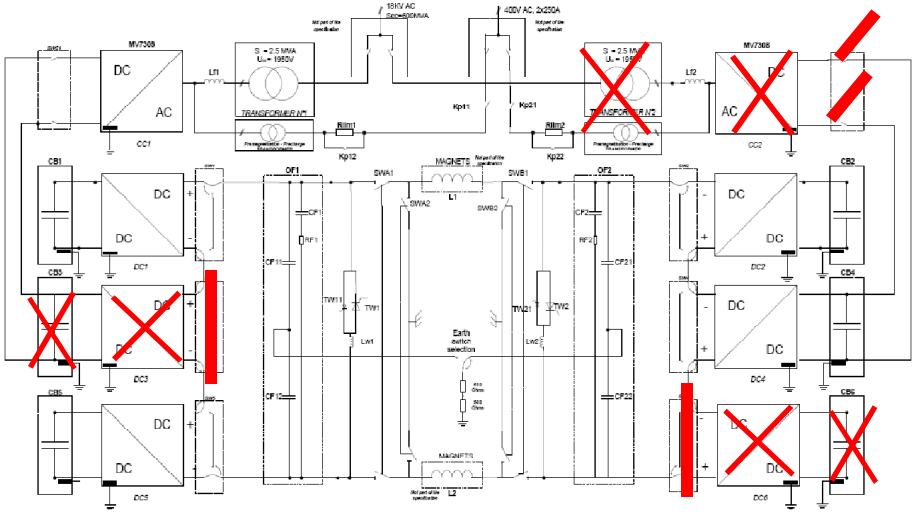


POPS operation

How POPS will not be a single point of failure?

No unique device!
POPS is modular and redundant

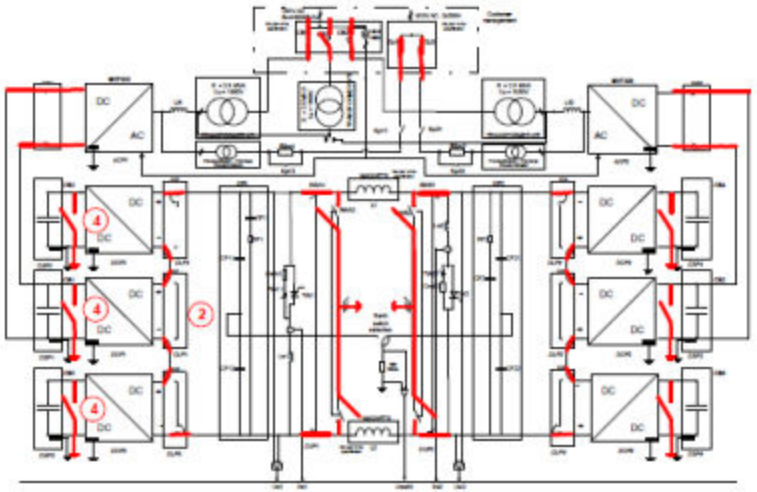
POPS can work with :
- ✓ Only 1 transformer over 2 (rms magnet current reduced by 40%)
- ✓ Only 1 AFE over 2 (rms magnet current reduced by 40%)
- ✓ Only 5 DCP over 6
- ✓ only 5 DSP over 6



POPS operation

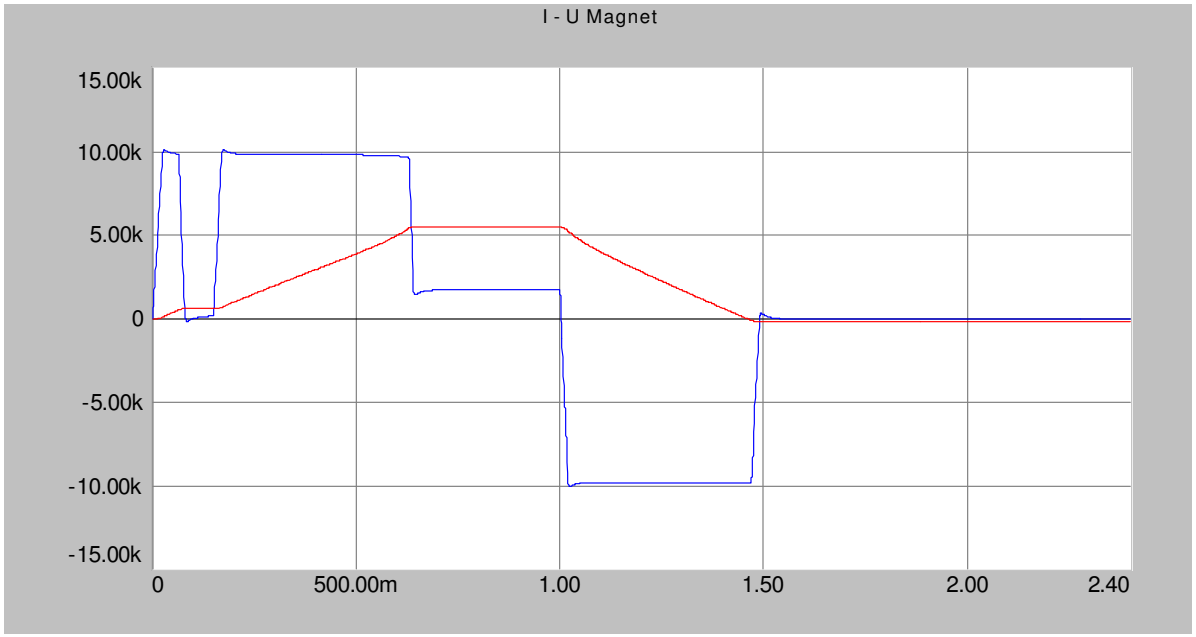
How POPS will be safer than MPS?

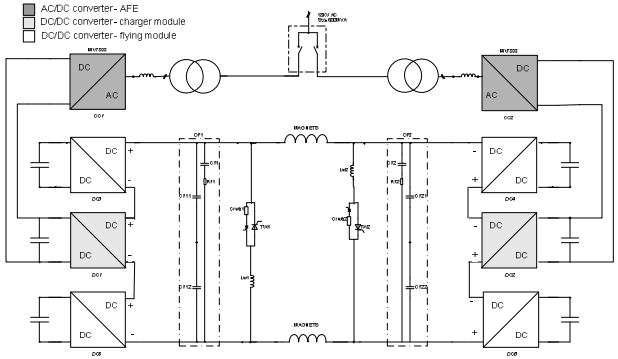
✓ POPS has a complete key locking system for doors and mechanical switches
✓ The configuration will be set by the HMI
✓ The key locking system will authorize operation
✓ The grounding is done with mechanical switches managed by key locking system



POPS versus MPS

Magnets current and voltage





Time from injection to flat-top = 500ms instead of 650ms with MPS

POPS can go faster than MPS: 26GeV/c cycle can be done in 1.2s!

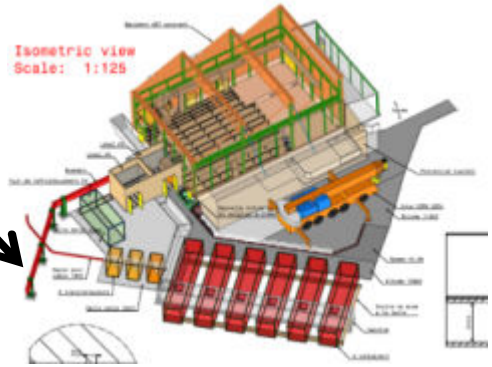
But the main limitation remains the RMS magnet current

POPS is designed for an equivalent RMS magnet current of 3.2kA

POPS, what is missing?

Still to be done: The DC connection to the magnets

The problematic: Cross the PS tunnel!



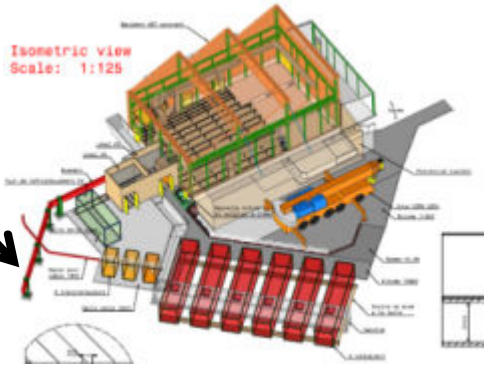
POPS, what is missing?

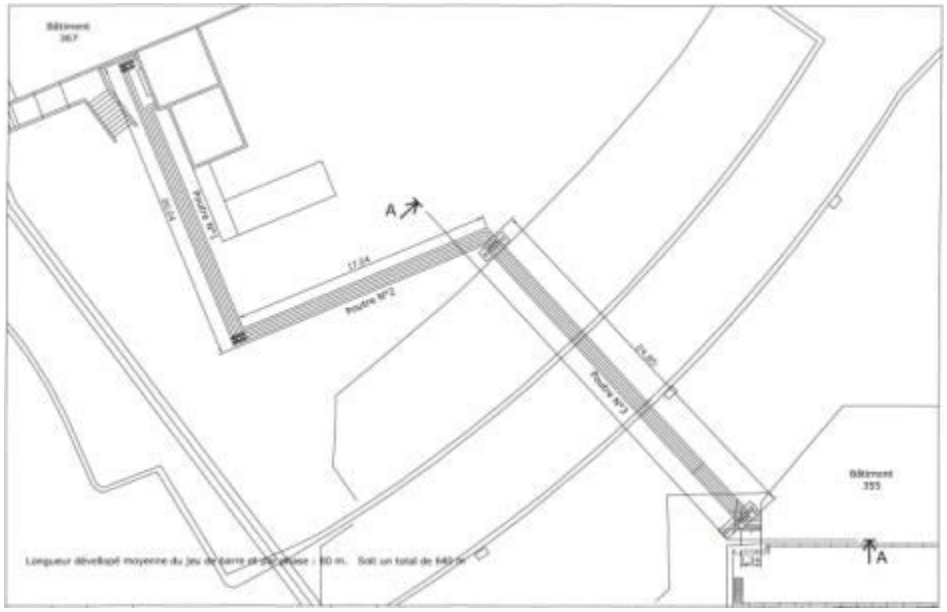
Constraint: No access during PS operation

Hypothesis: Don't touch the PS tunnel
no civil engineering over the tunnel

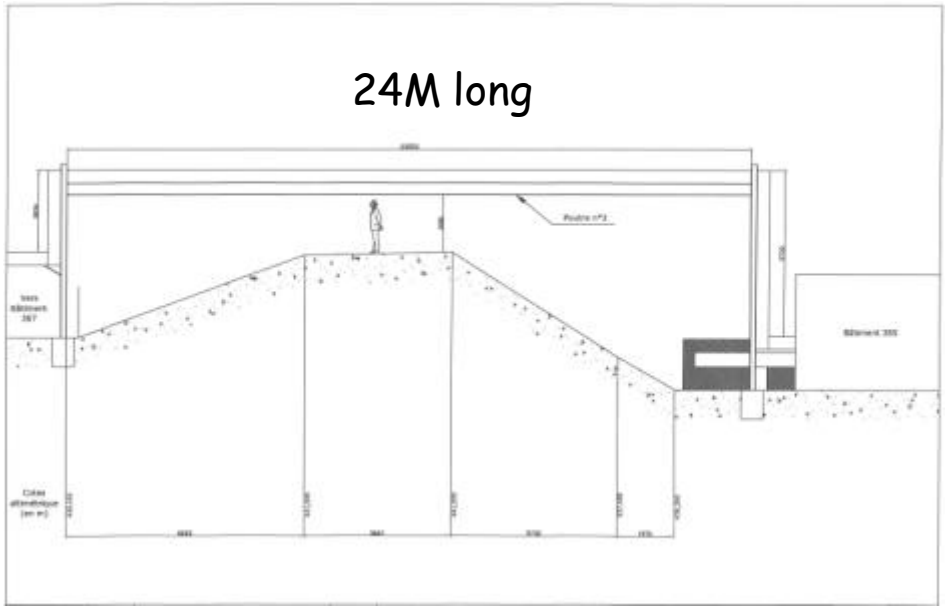
Solution: The bridge

The cost: over 1 MCHF





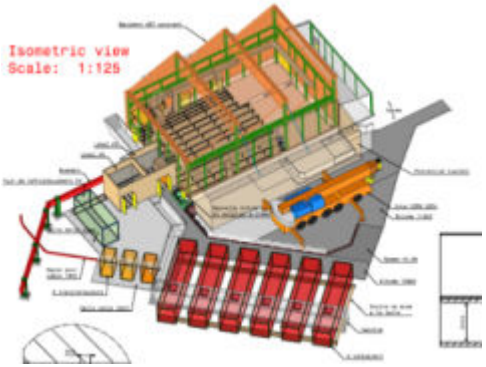
Total length 80m



24M long

DC link, cost killing

Review the hypothesis: dig over the PS tunnel

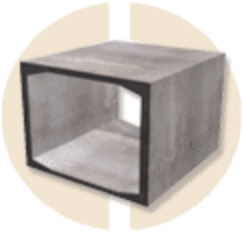


Make a cable duct
Place classical cable inside

8 cables (240mm^2) per polarity * 4 = 3km of cable

To be agreed with GS/SEM et PS landlord?

Don't show this to Lucio!



POPS, what else?

Commissioning is ongoing.

Final reception tests with Converteam planned in April 2010.

Still to be done: the DC link to the PS magnets

- Define the DC link solution
- Launch the purchasing of the material
- Prepare everything as possible in advance

DC link can be done in a shut down of at least 2 months

If the MPS has no problem during this run, POPS will be commissioned on the PS magnets after the next shutdown, 2011 ? 2012 ?
We already bought one more year of warranty (up to end of 2012)

If POPS has to start earlier, the cables can be put on ground in 2 weeks + 2 weeks of commissioning on load with CVT & CCC