



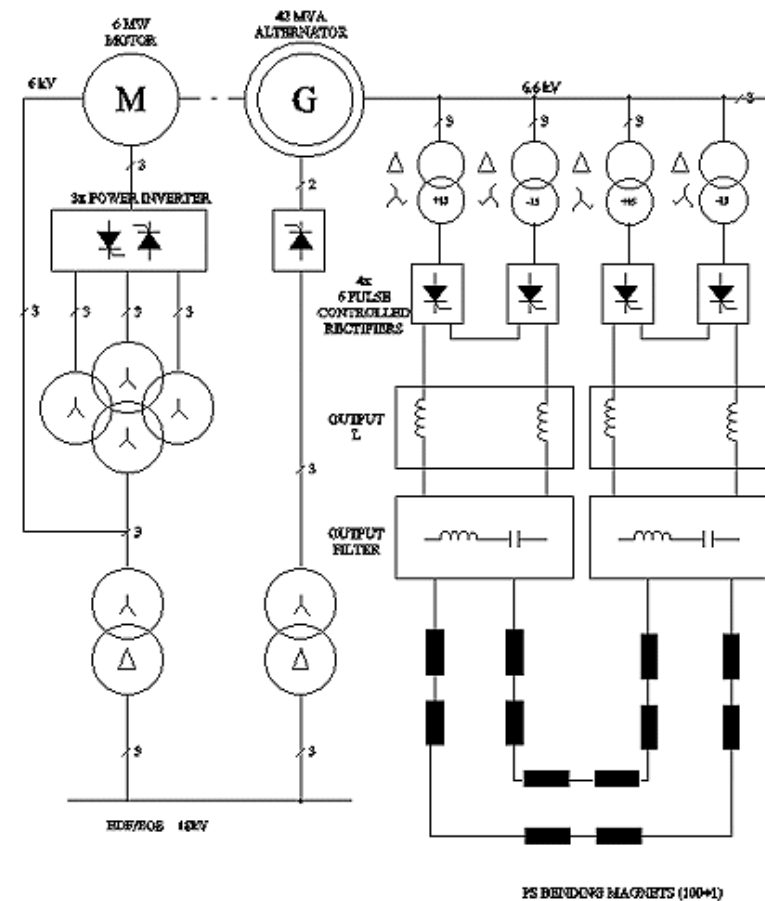
PS Main Power System:
What has been done from June 2006?
What will be the situation in 2007?

Jean-Paul BURNET, AB/PO

ATC-ABOC days, 22 January 2007

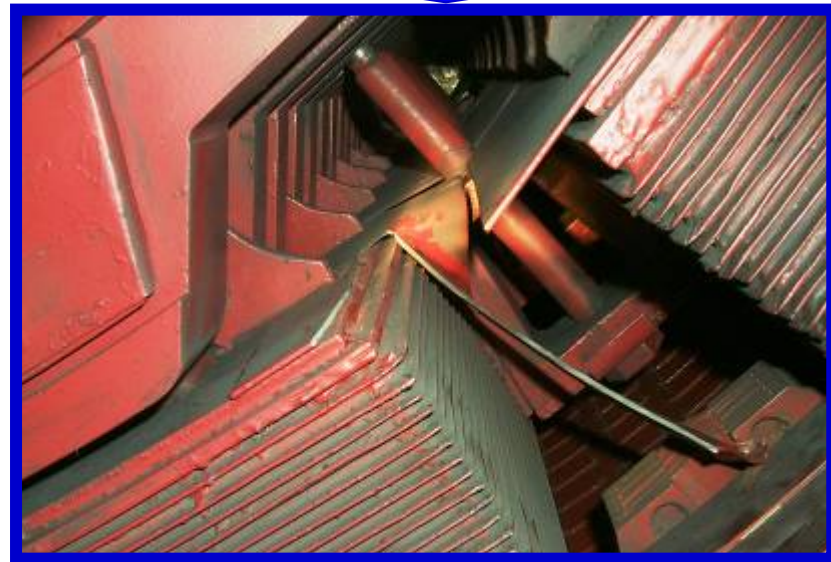
Introduction

- The PS main magnets are fed by a special power system including a Motor-Generator set (MG).
- The MG from SIEMENS is in operation since 1968.
- A high level of maintenance has been done on this system since the first pulse.
 - By SIEMENS for the rotating machine
 - By CERN for all the others parts
- Few numbers:
 - Number of cycles per year: 10 millions
 - Number of cycles since 1968: 380 millions!!!
- the previous BBC machine was kept as spare until the PS fire in 1975.
- Afterward, an electrical network supply with a 13MVA transformer was chosen as a backup system. Tested in 1980, never after!



History of the problems

- 2003: Technical audit of the MPS
- 2004: Audit conclusion: the MG is in good shape, it can pulse 10 more years
Earth fault on the generator's rotor!



History of the problems

- 2005: Installation of the spare rotor. Ask to Siemens to repair the broken rotor. How to repair?
- April 2006: Late offer from Siemens for the repair, CERN FC
- May 2006: Rotor repaired



History of the problems

- May 2006: Insulation material found in the air shaft. Rotor out of order!



- May-June 2006: MPS Stopped for 6 weeks to install the repaired rotor.



Friday 21st April 06:
transport to Hall 180

Back home...
24th May 06
Just in time!



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History of the problems

- Strong effort and very good support from SIEMENS
- June 2006: restart of the MPS with the repaired rotor
- Spare rotor:
 - The first rotor was changed in 1977 due to insulation material problem since 1973
 - It was refurbished and kept in spare since 1977
 - But probably, a light refurbishment was done with mastic



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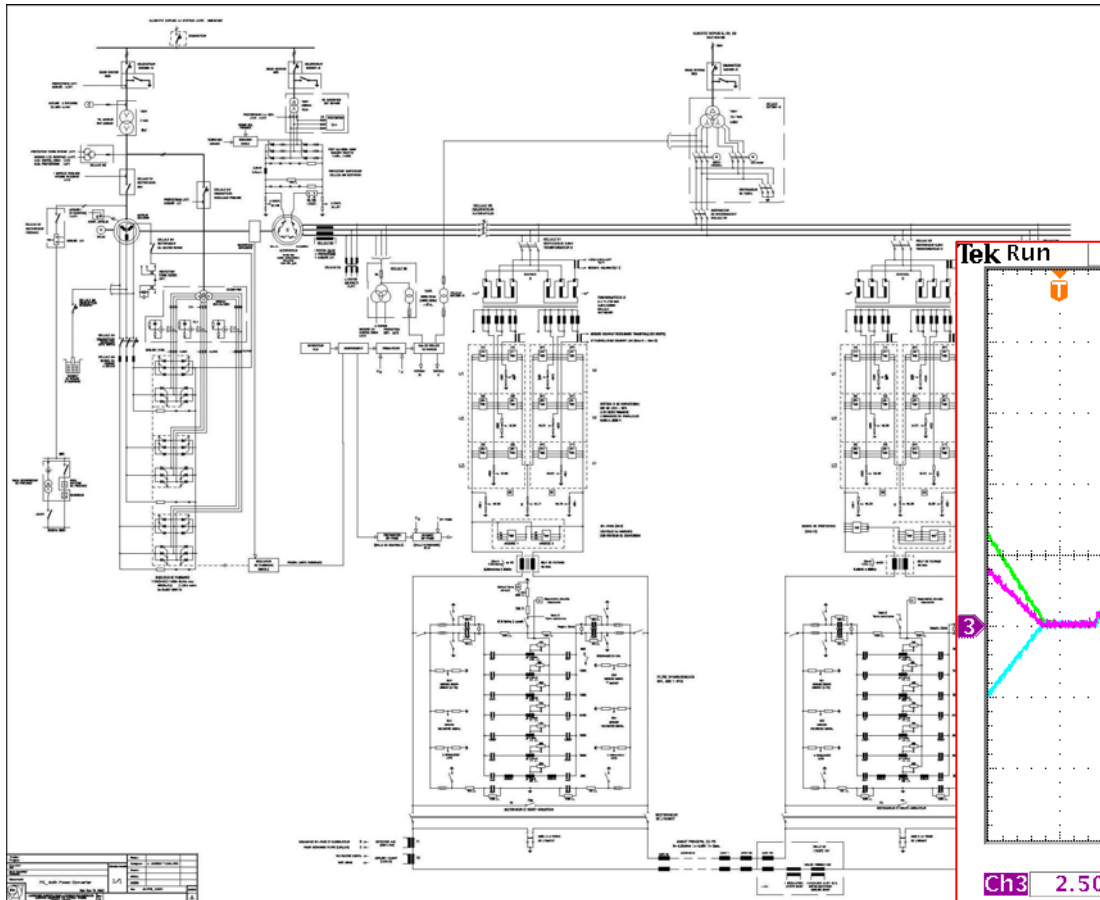


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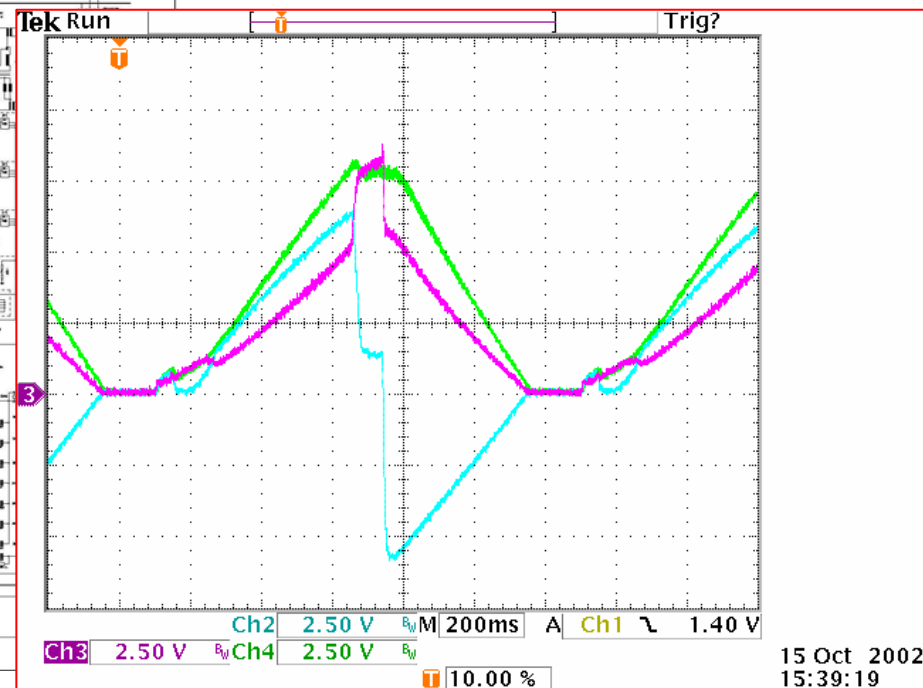
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History of the problems

- June 2006: Restart of the 13MVA back-up system
- 2 weeks in operation for SFTPRO cycles to fill SPS

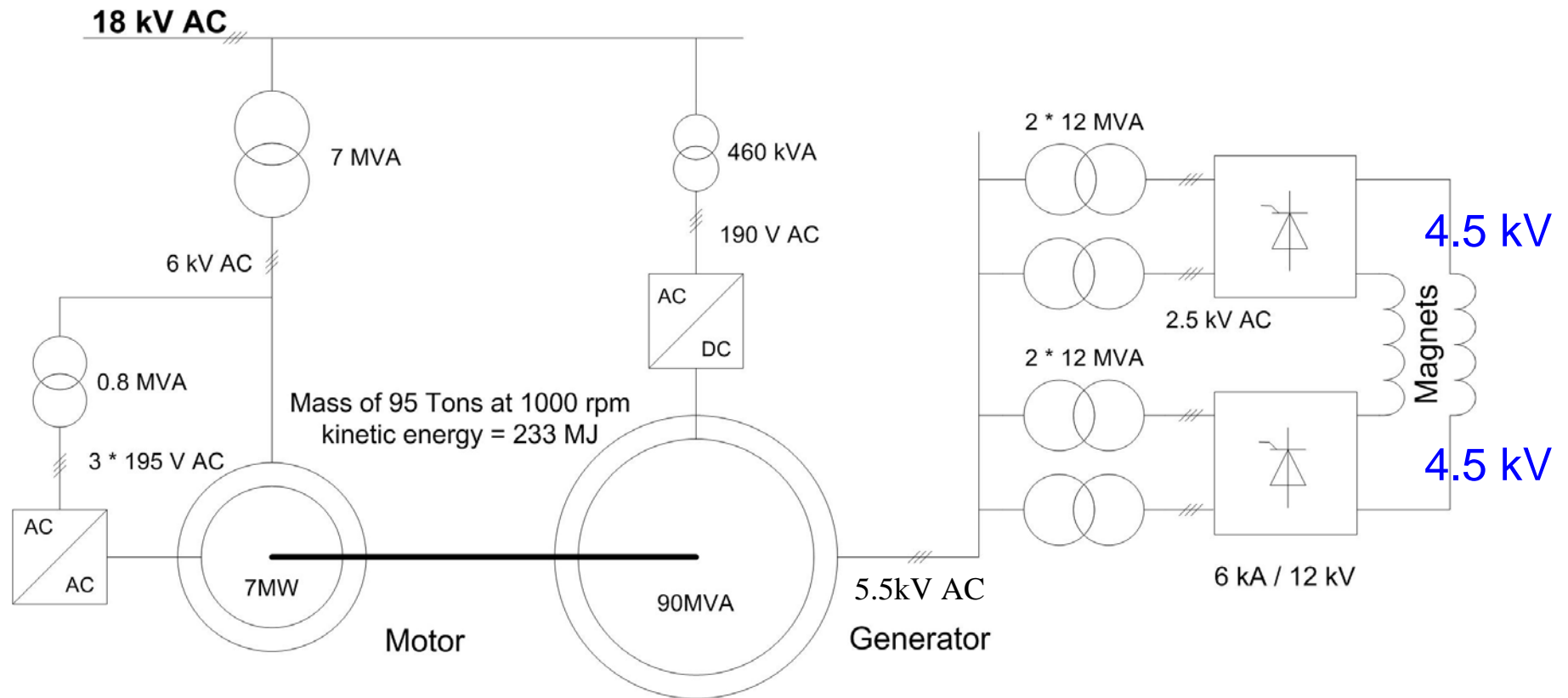


**13 MVA transformer
connected to SPS 18kV**



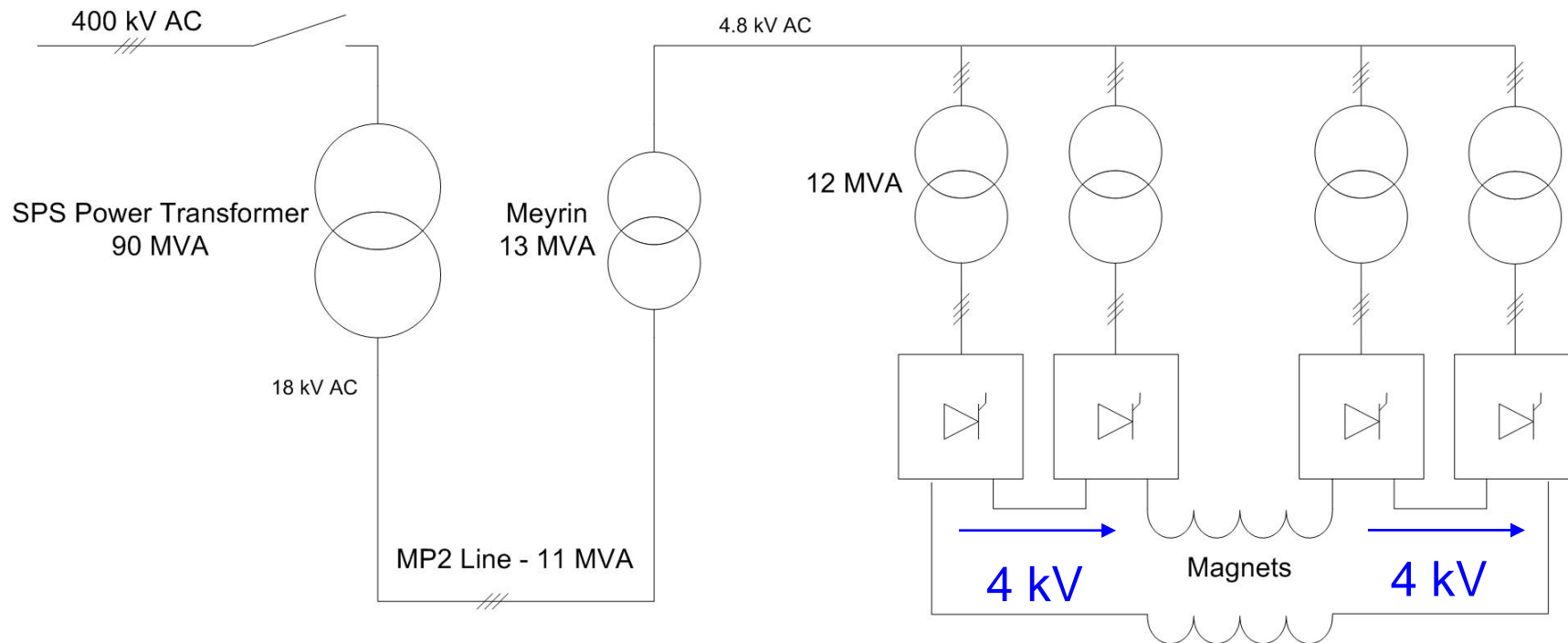
MPS with rotating machine

- The MPS rectifiers are normally fed by the 90 MVA rotating machine



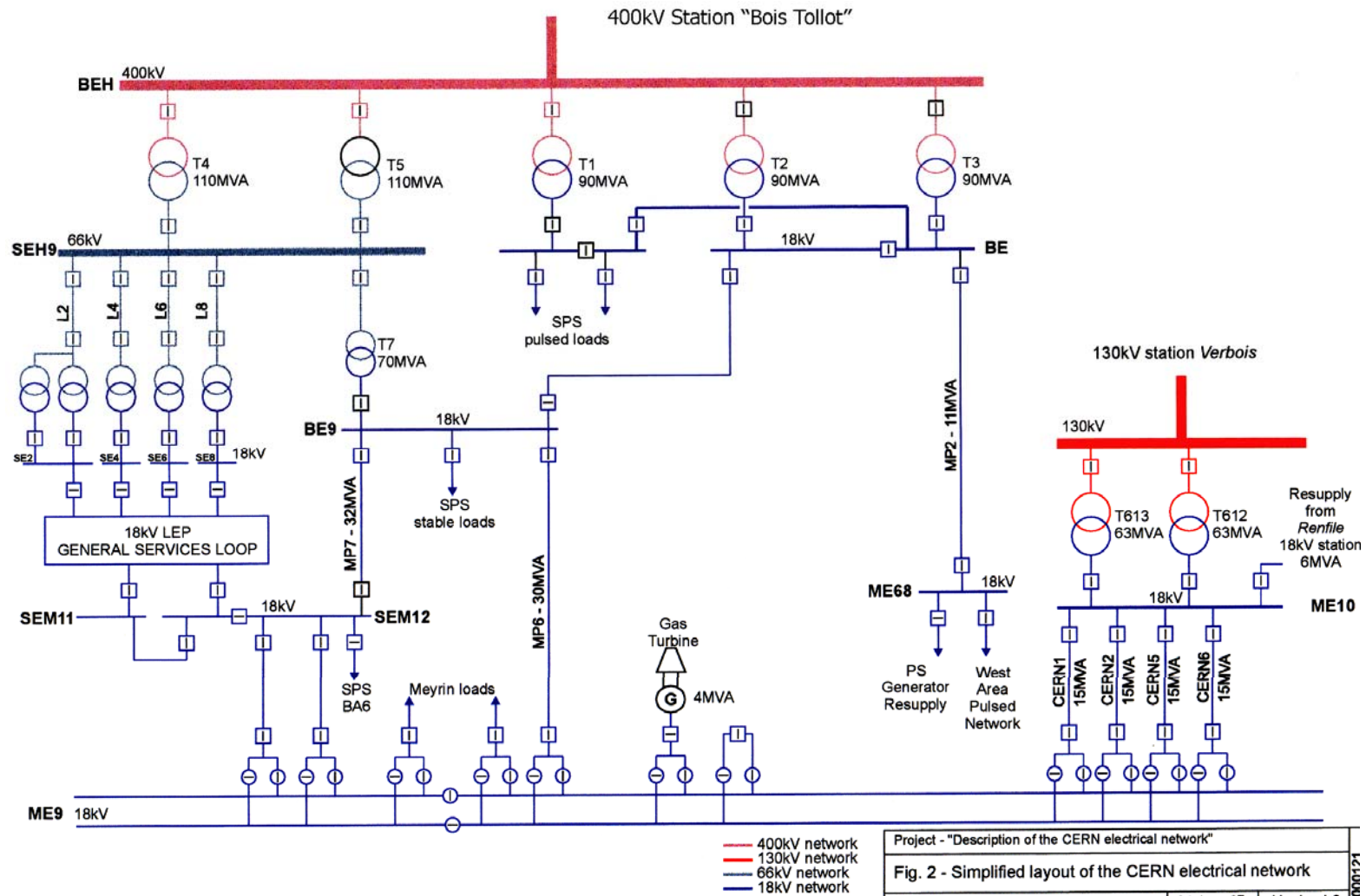
MPS with 13 MVA power system

- The MPS rectifiers can be fed by a 13 MVA transformer connected to SPS 18 kV.



MP2 line

- The MP2 line can be connected to the MPS. It is also use for Auto transfer.



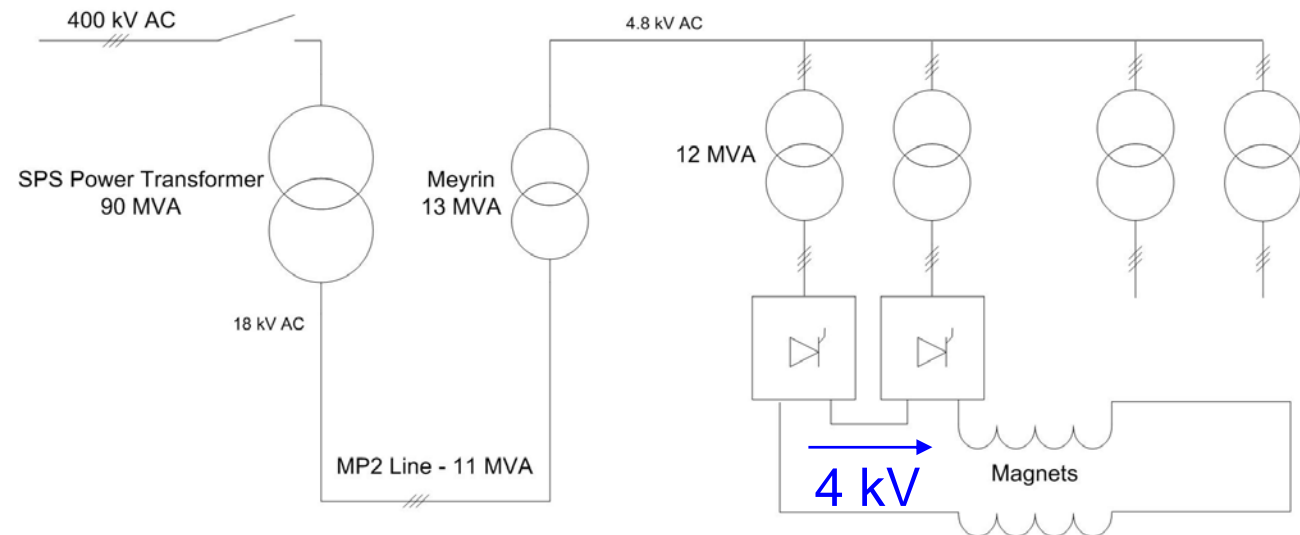
13MVA limitations

- The main limitations of the 13 MVA power system are:
 - The rating of the transformer: only 13MVA instead of the 90 MVA for the generator
 - The rating of the MP2 line (18kV): only 11 MVA
- SFTPRO cycles were done in June 2006
 - Maximum active power = 22 MW
 - Maximum reactive power = 27 MVAR
 - Maximum apparent power = 27 MVA
 - RMS 18 kV line current per cycle = 563 A
 - RMS 18 kV line current 1 cycle in 16.8s = 150 A
 - RMS 18 kV MP2 line – 11 MVA = 353 A

 - Maximum magnet voltage = 8 kV
 - Maximum magnet current = 2.9 kA
 - Bdot = 0.93 * standard Bdot

26 GeV cycles

- 26 GeV cycles can not be done with two stations (9 kV)
 - The power distribution is too weak (11 MVA)
 - The overload is too high (60 MVA) for the 13MVA transformer
- Solution
 - Use only one station to supply the magnets
 - Only 4kV applied to the magnets, Bdot divided by 2.7
 - Max power divided by 2 (Reminder: Max cycle tested in 1980: 20GeV)

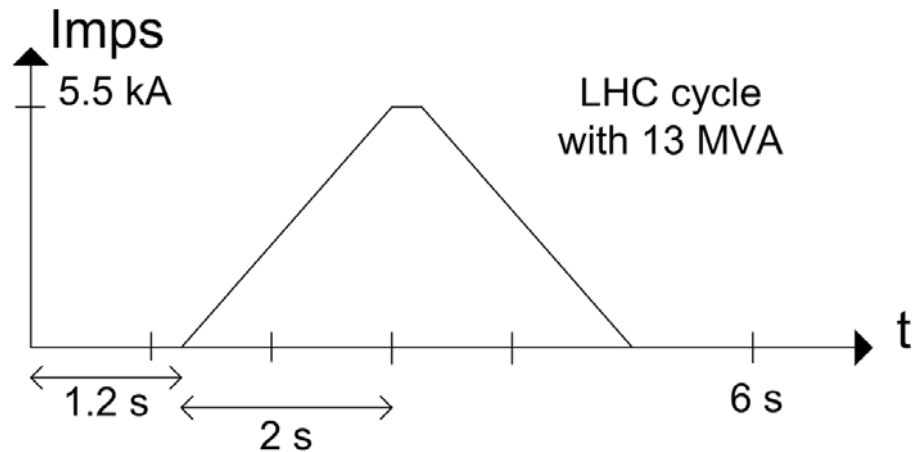


26 GeV cycles

- LHC cycles with one station

- Rise time = 2 s
- Cycle length with double injection = 6 s
- Maximum active power = 22 MW
- Maximum reactive power = 25 MVAR
- Maximum apparent power = 27 MVA
- RMS 18 kV line current per cycle = 460 A
- RMS 18 kV line current for 4 cycles in 60s = 354 A
- RMS 18 kV MP2 line – 11 MVA = 353 A

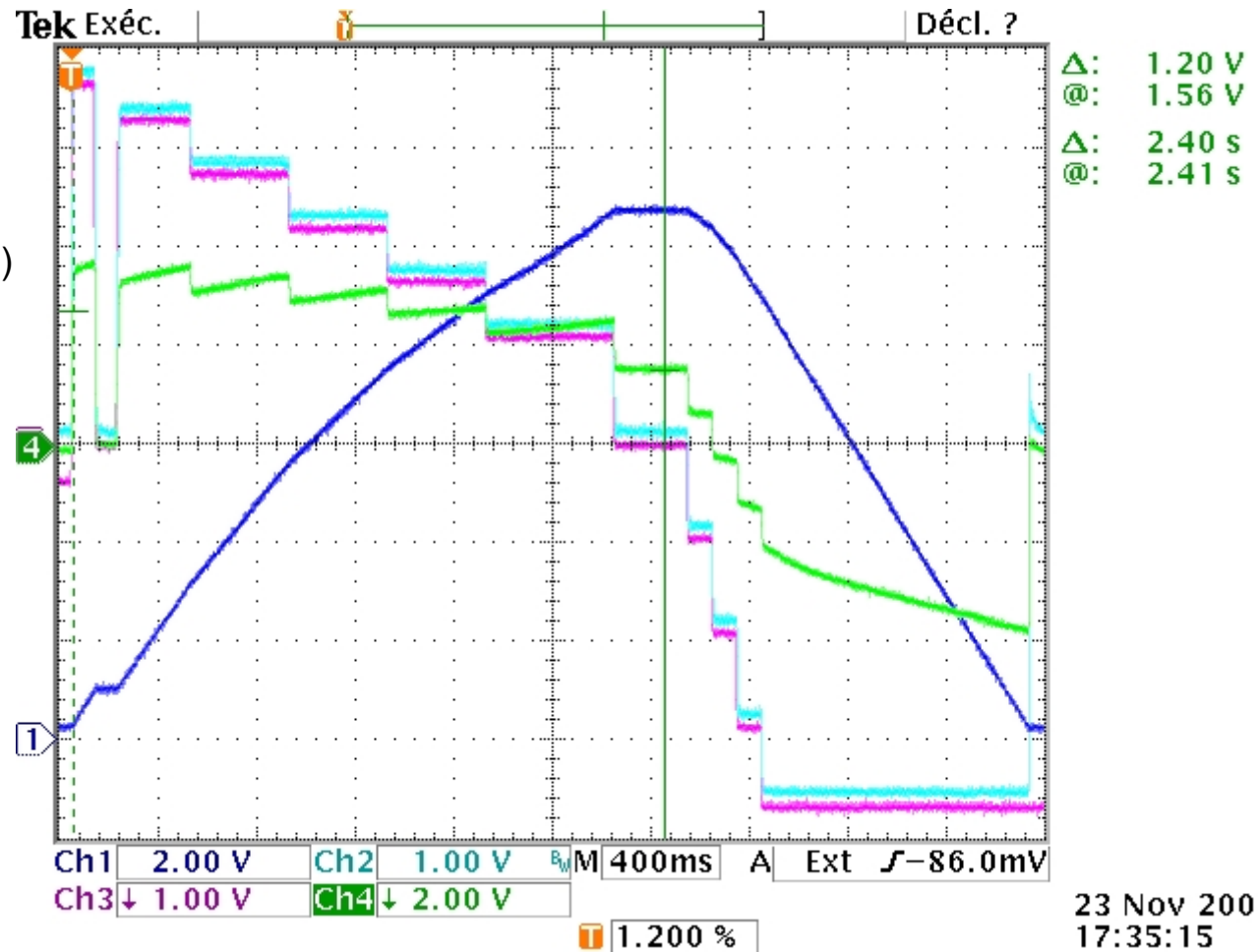
- Maximum magnet voltage = 4kV
- Maximum magnet current = 5.5 kA
- Bdot = 0.37 * standard Bdot



Results of the power tests

- Injection time: 0.2s
- Rise time: 2s
- Flat top: 0.4s
- Fall time: 1.4s
- Cycle : 4s (on 4.8s)
- Max voltage: 4kV
- Voltage end of ramp: 2.5kV
- Max B field: 12417 Gaus

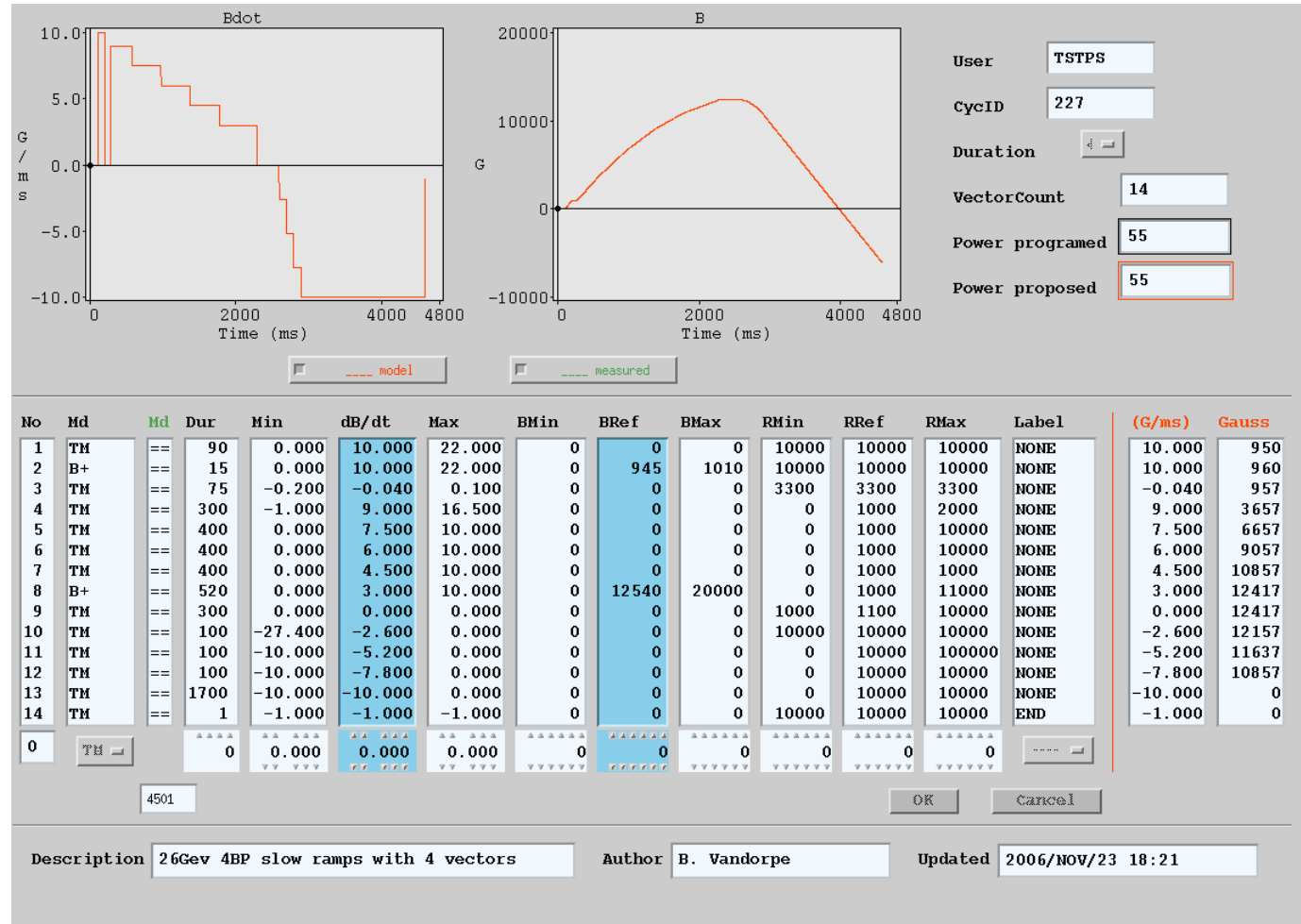
Blue: magnet current
 Green: magnet voltage
 Purple: Bdot
 Light blue: Bdot reference



Results of the power tests

Max Bdot: 10G/ms
At the end of ramp: 3G/ms

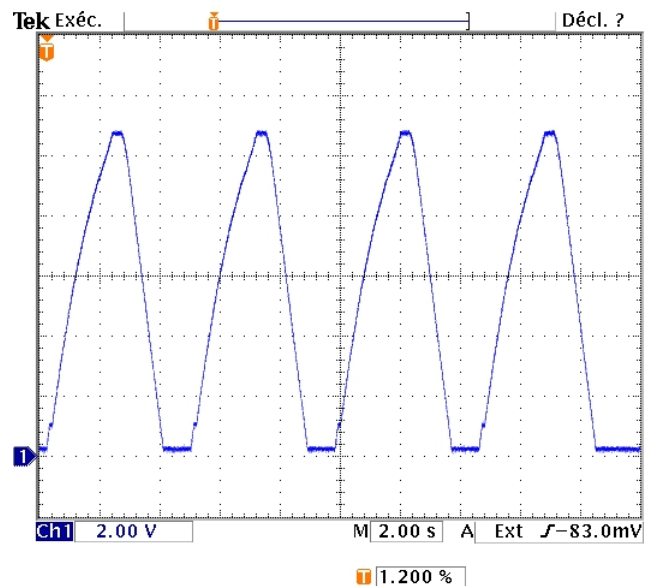
With MG :22G/ms



13MVA summary

In case of MG breakdown, the 13MVA backup system will be used.

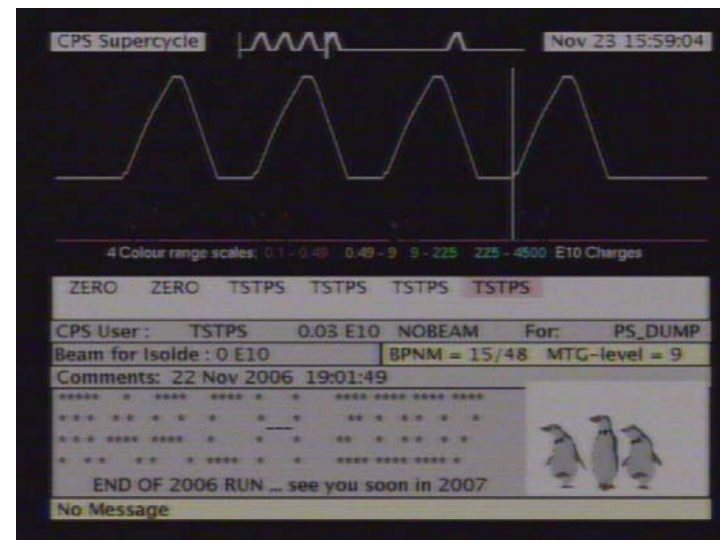
- LHC cycles will be done in 6s (double injection)
- Ions cycles will be done in 4.8s (single injection)
- SPS cycles will be 28.8s ($3 * 6s + 10.8s$)
- Four LHC cycles can be done every 57.6s
- The LHC will be filled in 60' instead of 21'
- LHC beam will be close to the nominal intensity, see APC conclusions (06/07/06)



22-01-2007

23 Nov 2006
17:46:51

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MPS situation

- September 2006: Project approval by DG for a new PS power system
- No “more” spare rotors: cost of the repair is too high, 2.6 MCHF!
- The only backup for the rotating machine is the 13MVA transformer
 - 14GeV cycles were done in June 06
 - 26GeV cycles were tested in November 06
- In case of breakdown, CERN could ask to SIEMENS to repair the rotor.
The repair can take up to one year.
- Maintenance and upgrade will continue until the start up of the new power system
 - Thyristor spares increased
 - New 135kW power resistors will be purchased for filters
 - Transformer oil will be treated

Experience from BNL

- Brookhaven National Laboratory has a similar SIEMENS rotating machine for AGS
- They had a first event in 1996 on the baffles (like us)
- They asked to GE to do the repair to save money
- After the repair and after two months of operation in 2001, one new piece of the rotor broke and destroyed the stator
- They had to repair another time the rotor plus the stator!
- The total cost of the repairs was 6M\$
- They will do an upgrade of the rectifiers and transformers for 3M\$
- Hopefully, BNL has a half power spare MG



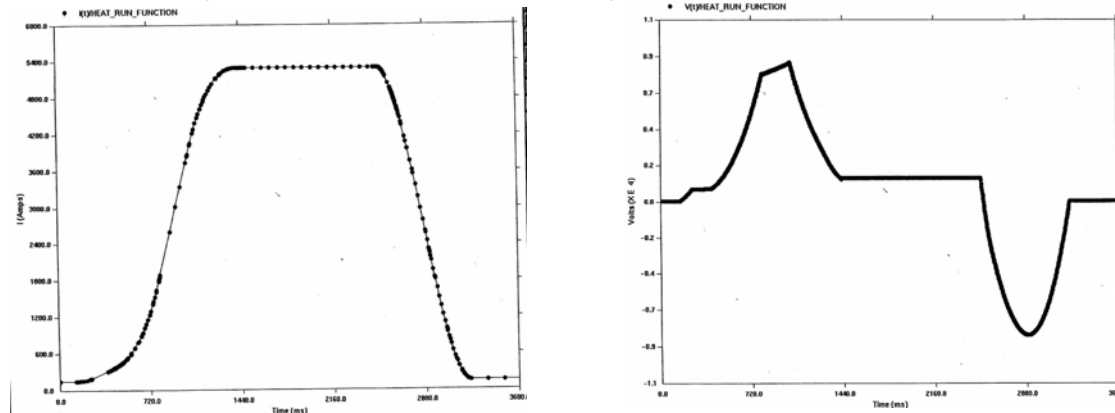
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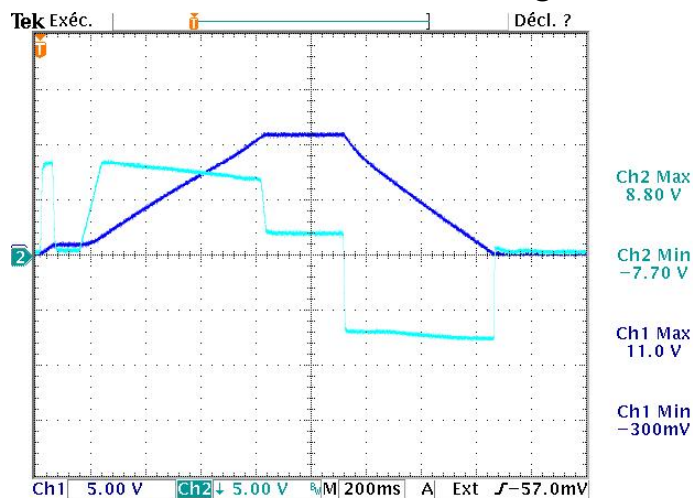
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Experience from BNL

- AGS cycles are very smooth and slow compare to the PS !
- They run few hours per day and each week, they stop the MG for 8 hours of maintenance !

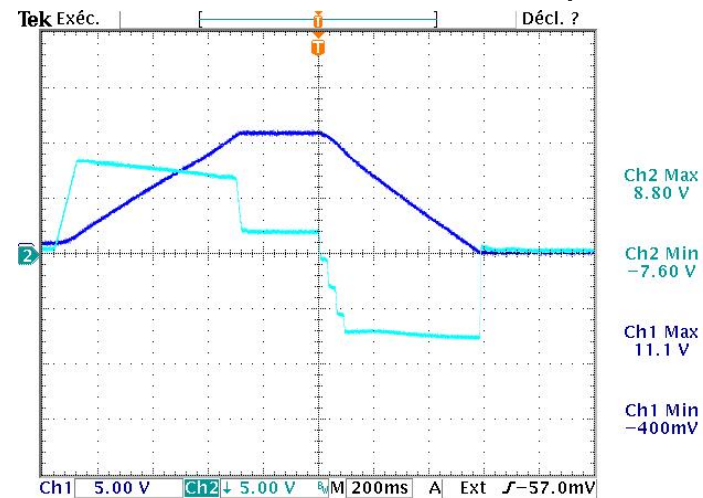


- They were surprised by the violence of our cycles ! =>
- We tried to reduce the stress during the torque inversion at the end of the flat top!



28 Sep 2006
14:07:10

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28 Sep 2006
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ABMB slide

The PS rotating machine is now almost 40 years old.

A high level of maintenance has been performed up to now.

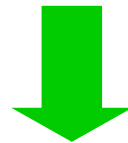
Nevertheless, the initial expected life time of the system is almost over.

We want to outline the high failure risk linked to the present rotating system.

This rotating machine is the key element of the system.

If a very high failure occurs on the PS machine can be down for one year.

DYNAMOWERK engineering director comment



**We recommended to the top management
To invest in a new power system**

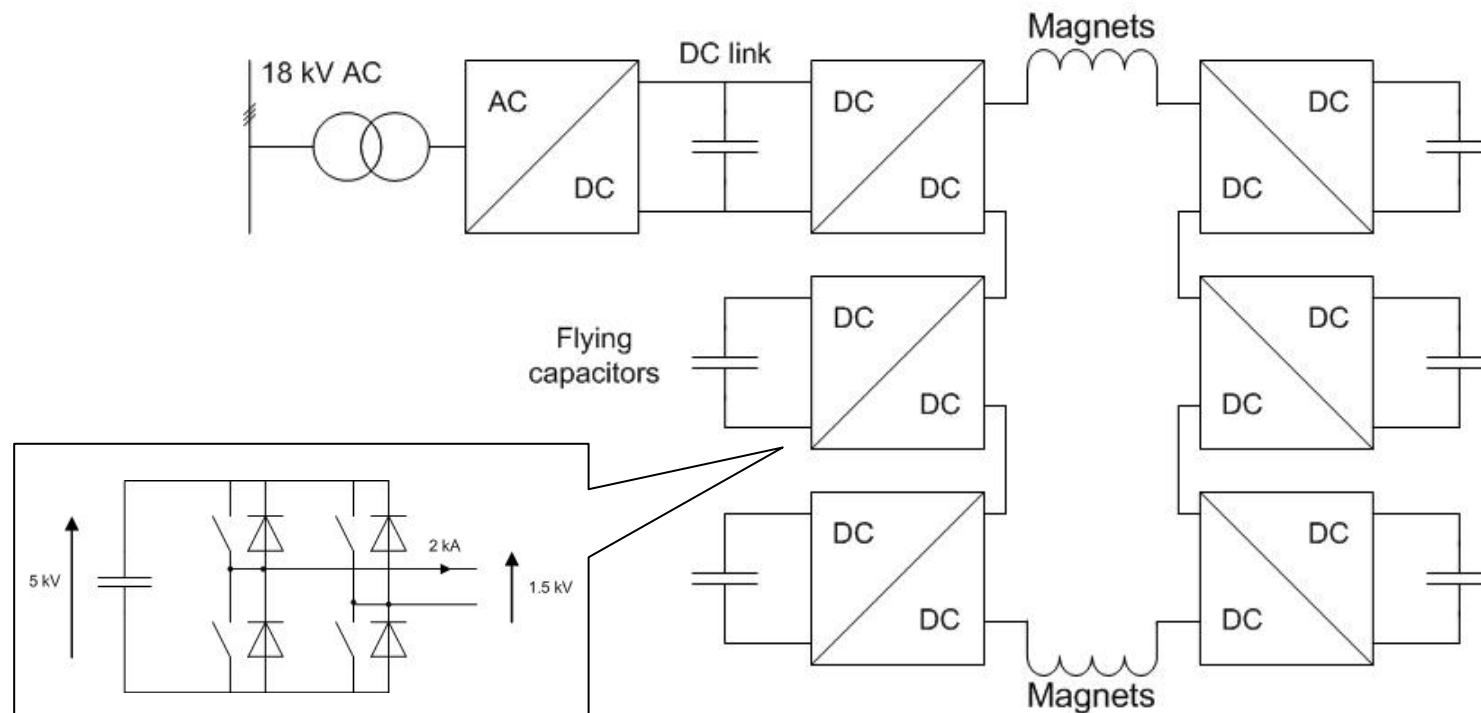
Studies for a new MPS

- Which solutions are available to replace the present power system?
 - Studies started in 2003
- Motor-generator:
 - No more an industrial solution
- Electrical network
 - Connect the rectifiers to the 400kV
 - Industrial solution but costly
 - Active power taken on the 400kV. $\pm 50\text{MW}$ with a mean power of 4MW!
 - Alternative: STATCOM with capacitor banks
- New concept
 - Store energy in capacitor or SMES
 - No industrial SMES (Superconducting magnetic energy storage)
 - Industrial ready to build a power system with capacitor banks
 - Only the losses of the system will be taken on the mains (10MW)

Green solution!

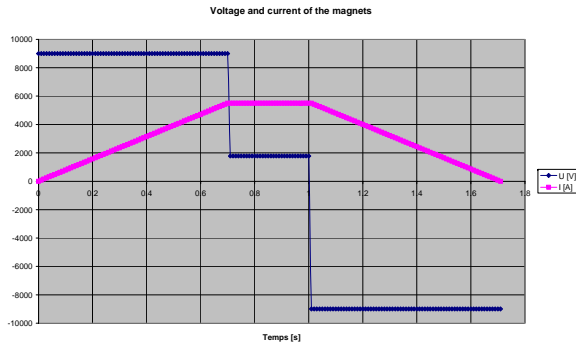
MPS with capacitive energy storage

- Use capacitors to store energy and to exchange it with the magnets
- Directly integrated in the power converter
- Classical dry capacitors 5 kV, 1F, ~1000 caps in 6 banks (7m * 2m * 2.5m)
- New concept based on industrial products (Medium Voltage Drives)
- Outdoor containers and modular
- Turnkey system

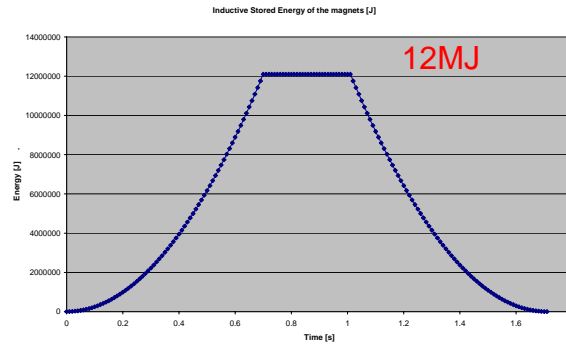


MPS with capacitive energy storage

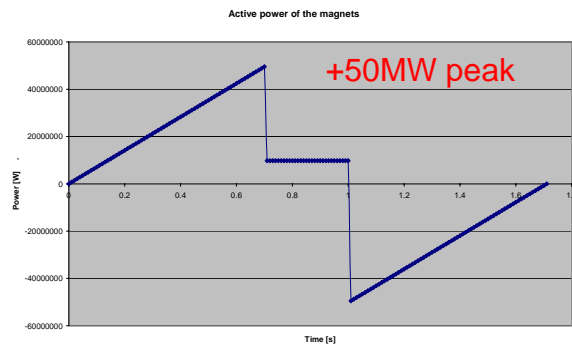
Magnets current and voltage



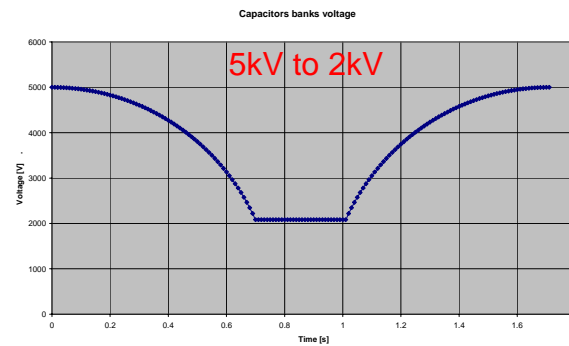
Stored magnetic energy



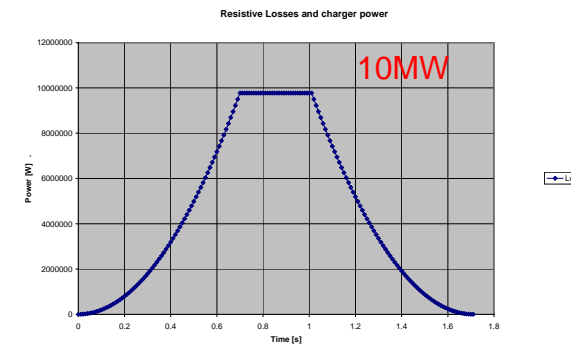
Magnets applied power



Capacitor banks voltage



Power from the mains

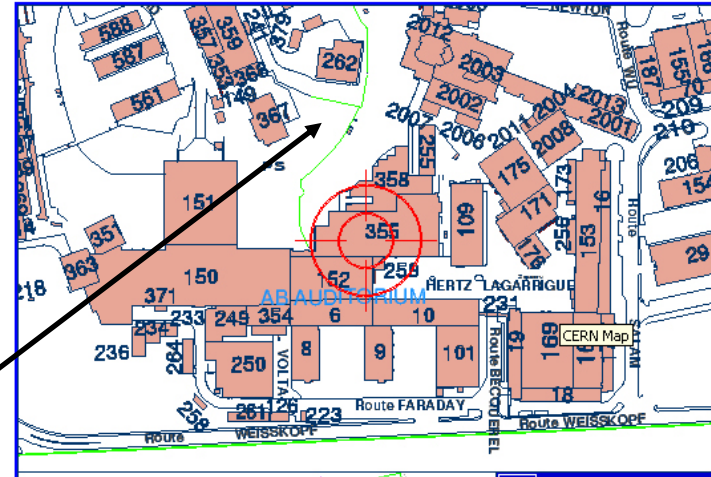


New MPS

Outdoor containers



PS centre anneau



Capacitor banks

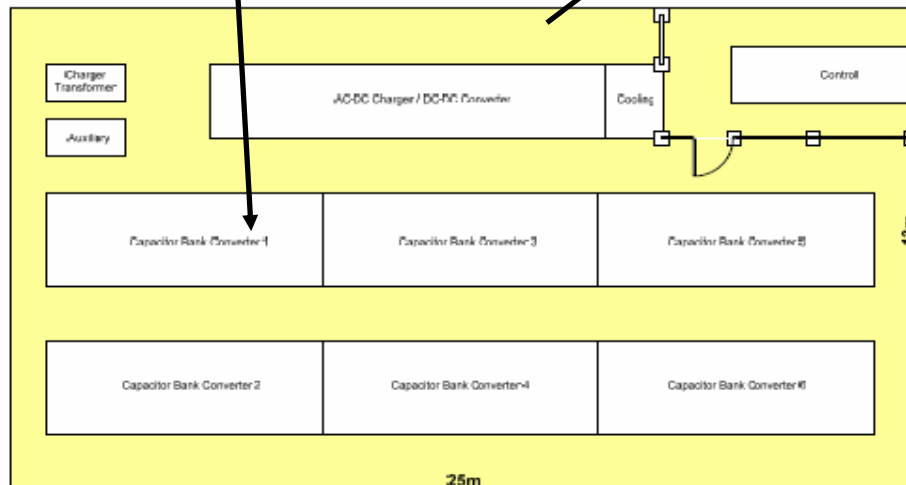


Figure 6: System Layout PULSE POWER CONVERTER

B.5.2 Capacitor Bank

Each DC-DC Converter requires its own Capacitor Bank with total 224 Cans. Similar as for the power electronics each Cap Bank will be delivered in a frame, see Figure 9.



Figure 9: Capacitor Bank, example energy storage for the DVR Israel

Figure 10 shows the space requirements for one 282mF Capacitor bank.

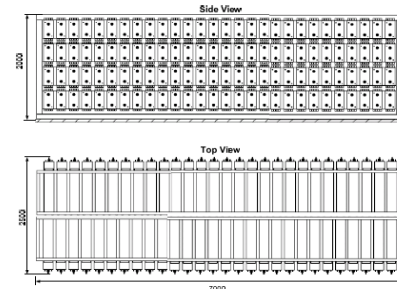
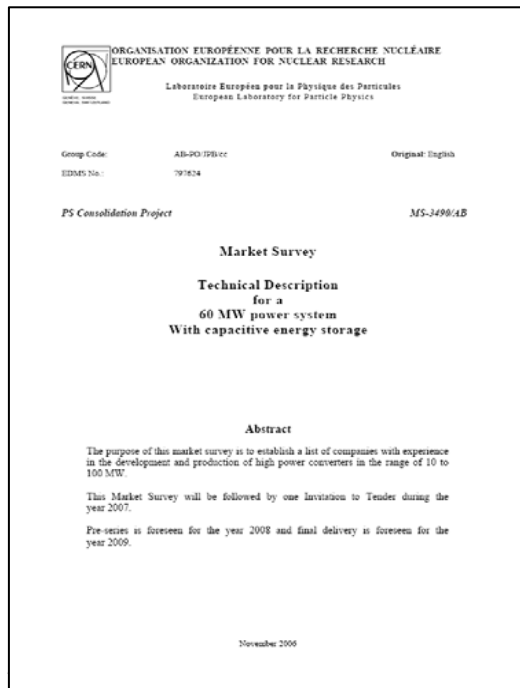


Figure 10: Configuration of one 282mF with total 224 Cans.

Where are we with the new MPS?

- MS-3490/AB started 1st December 06
- Functional specification under approval
- Contract expected after FC of September
- First power test in 2008
- Installation and final power test in 2009
- Operation in 2010



CERN
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AB consolidation

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EDMS Document No.: XXXXX

Date: 2006-03-02

Functional Specification

**NEW POWER SYSTEM
FOR THE PS MAIN MAGNETS**

Abstract
This document describes the functional specification of the new main power system for the PS accelerator. This system will replace the present power system including the 90MVA rotating machine.
First, the present power system will be presented. Second, the new power system will be introduced with the major changes foreseen. The planning of the project will also be presented.

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Conclusions

- After the repair, the MPS operated normally last years
- In case of breakdown of the MG
 - No more spare rotors
 - Only one backup system: 13MVA transformer
 - LHC cycles can be done with this backup system
- The physics program will be limited:
 - LHC or
 - 2 SPS + 1 EAST every 20s Compare to
 - 2 SPS + 4 EAST + 1 TOF + 1 AD + 1 TSTLHC every 18s
- The purchasing of the new power system started with the MS-3490/AB
- Contract is expected in September
- The new power system is expected to be in operation in 2010
- **PULSE THE PS ONLY WITH BEAM. EACH PULSE COUNTS!!!**

We need the rotating machine for the next 3 years