Methods of improving reliability with spares, hot spares, switchable spares, built in redundancy

Hans-Jörg Eckoldt

19.05.08

1. POPCA Workshop Trieste

Structure

- Strategies
- Examples from HERA
- R&D done for TESLA, XFEL, FLASH
- Design for PETRA III

Ingredients for improvement of reliability

- Over dimensioning
- Spares
- Hot spares
- Switchable spares
- Built in redundancy

What is the correct choice?

- The correct choice of ingredients comes from the overall strategy of the machine project management.
  - It depends on the available money
  - General aim of the machine
    - High energy physics
    - Light source
  - Operation scheme
  - Accessibility of the power supplies

DESY MKK

Examples

- In HERA-machines the experiments where installed in the machine for the entire operation time.
- The power supplies were reachable within reasonable time
- Therefore the down time was “tolerated” in the design. The power supplies were built in a modular way and had to be replaced in case of failure. Speeding up of the repair is possible by good education of shift crew and a sufficient number of spare parts and tools in the halls

Hans-Jörg Eckoldt

Main Dipol Power Supply
8000 A/+500V,-300V

Hans-Jörg Eckoldt

Chopper in HERA

Hans-Jörg Eckoldt

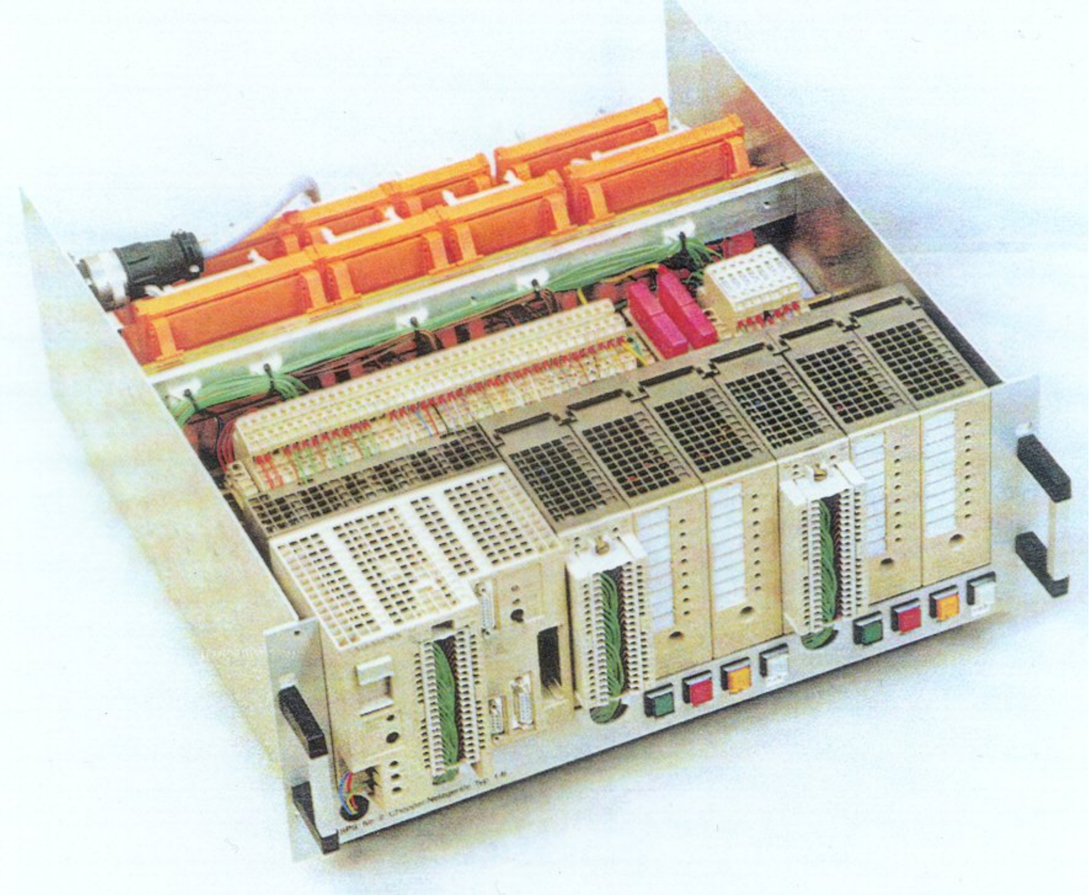
Grounding System for Magnets and SCR Supplies

- Each magnet can be grounded for tunnel access
- Remote control from control room
- Current sensors in the ground bus bars

Regulation electronic

- DAC for 16 or 18 bit
- cascade control with voltage sub loop
- trip for over current and mal function

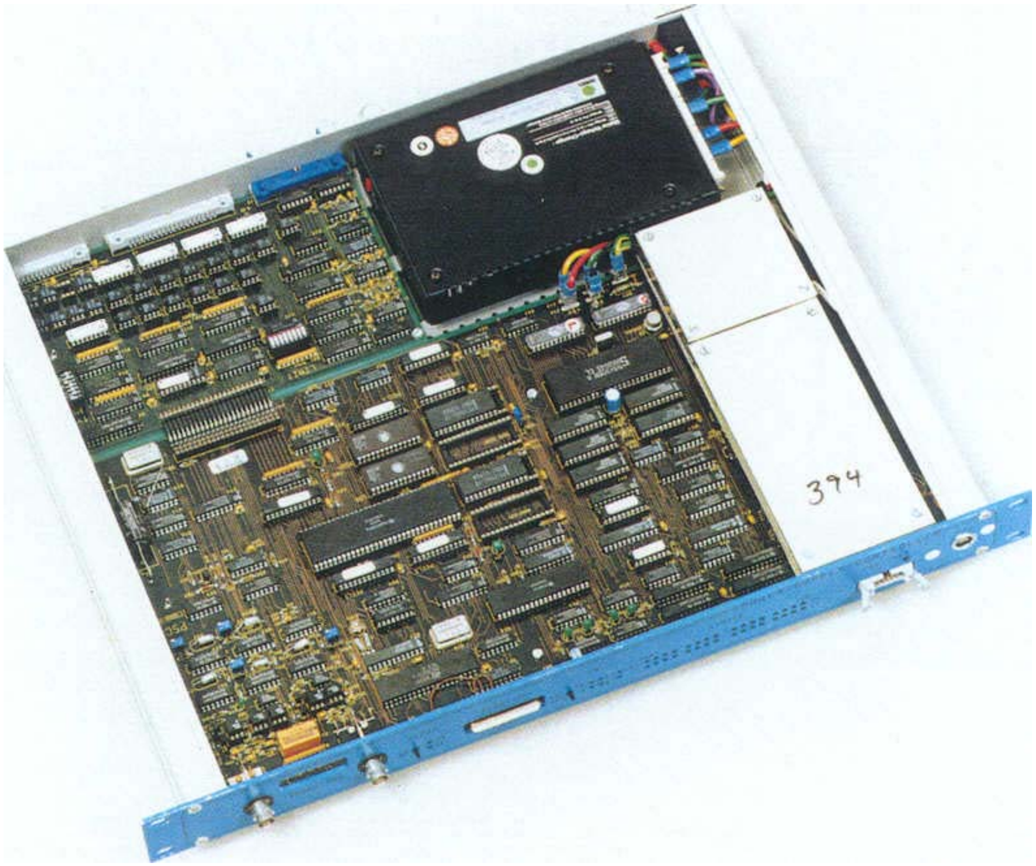
Programmable Logic PLC



- Protection against over current and over voltage
- Supervision of technical interlocks
- Industrial standard
- Local and remote control

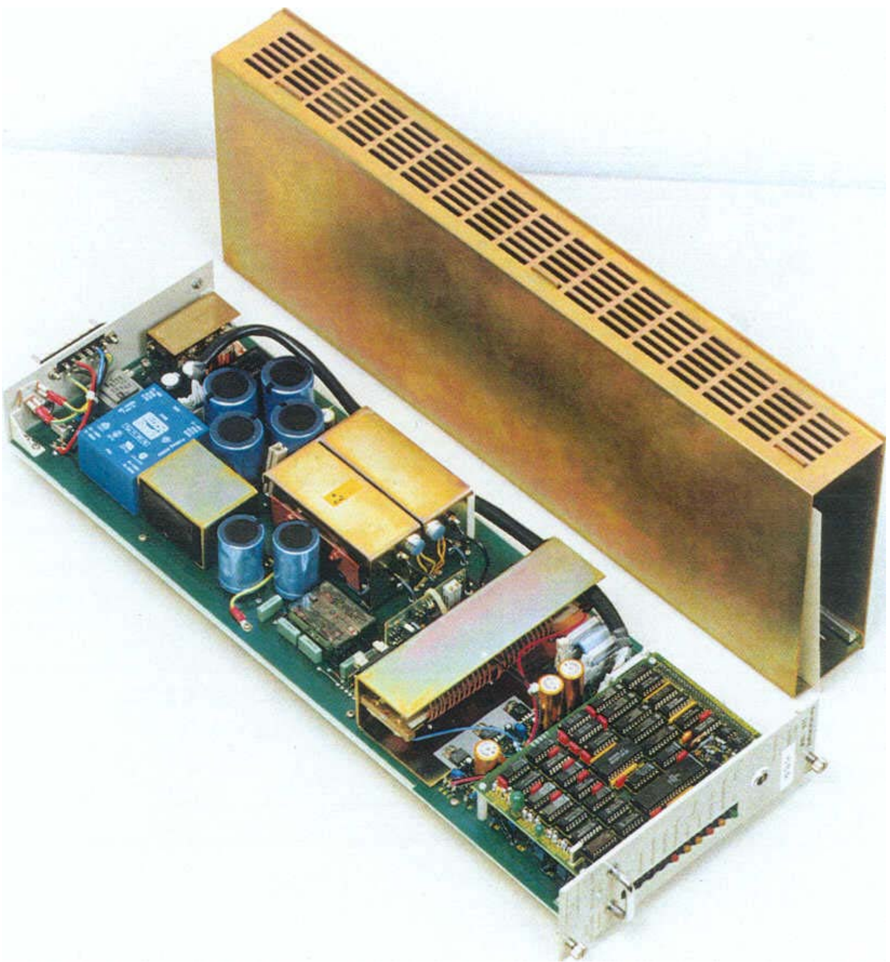
Hans-Jörg Eckoldt

Power Supply Controller (PSC)



- Interface between power supply and control system
- commands on/off, reset, etc.
- reference current, 16 or 18 bit
- actual value current via DVM
- status and alarms
- 700 units installed

Correction Power Supply



- 3,5 A to 20A
- 15 V to 120 V
- Primary switched, secondary switched
- Pole reversal
- Two current shunts
- 600 units for HERA, designed in 1986
- Excellent reliability
- Current error < 10-4
- Overall 1500 units

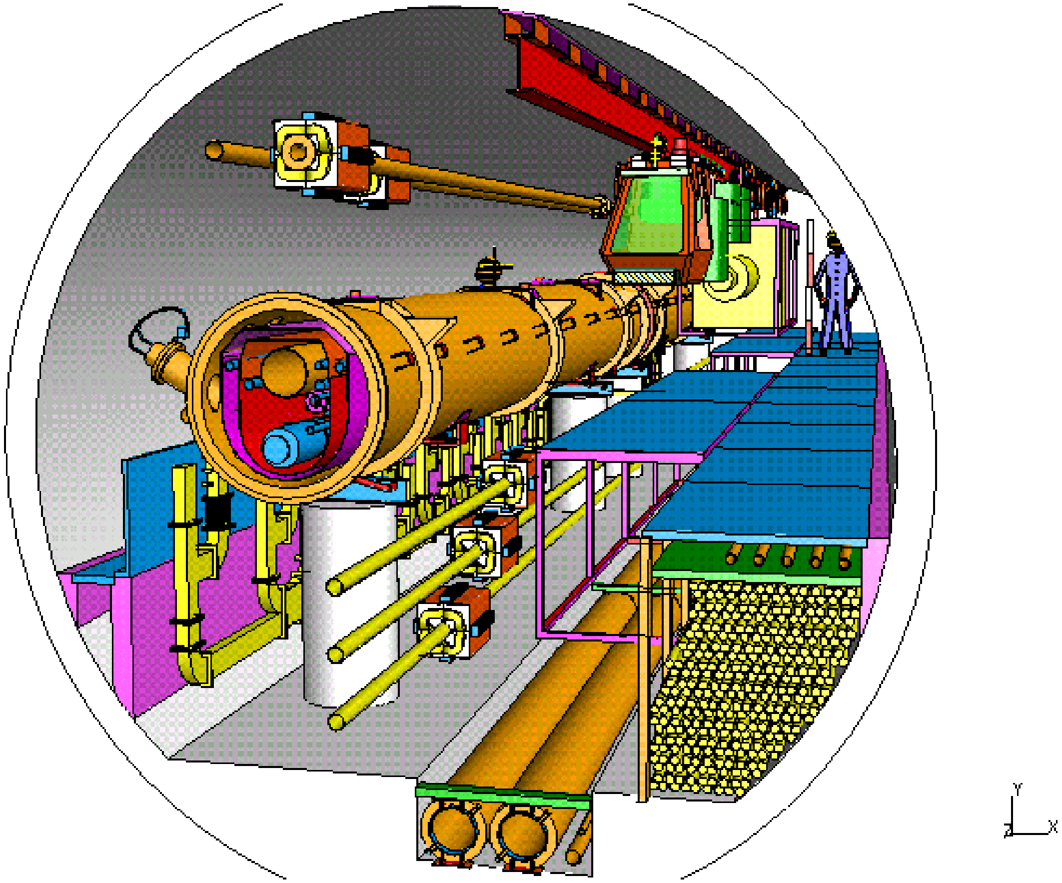
Strategies developed for TESLA, TTF-VUVFEL, XFEL

TESLA

- At DESY the R&D for a 30 km long superconducting accelerator was done. During this phase it was looked at the power supplies in order to increase of the reliability. The work is continued now for the ILC.
- The power supplies should be installed inside the tunnel.
- Baseline: Only 1 shutdown day per month was foreseen for the access.
- All repair had to be planned for this day.
- There shall containers for the housing of the components in the tunnel. These containers shall be exchangeable

Hans-Jörg Eckoldt

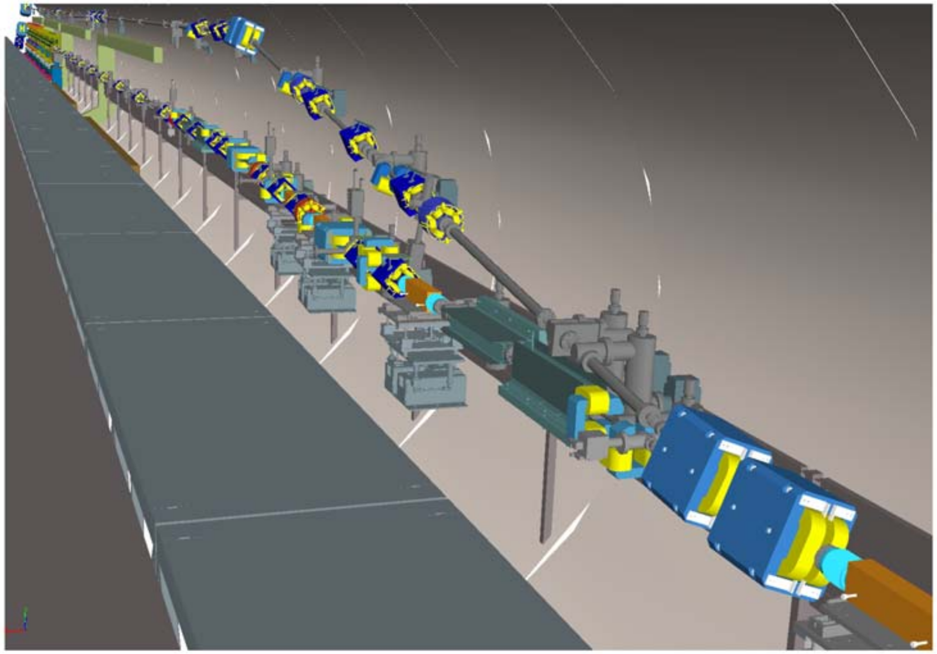
View into TESLA tunnel (old design)



Hans-Jörg Eckoldt

Flash Tunnel
FLASH started a TESLA Test Facility (TTF)

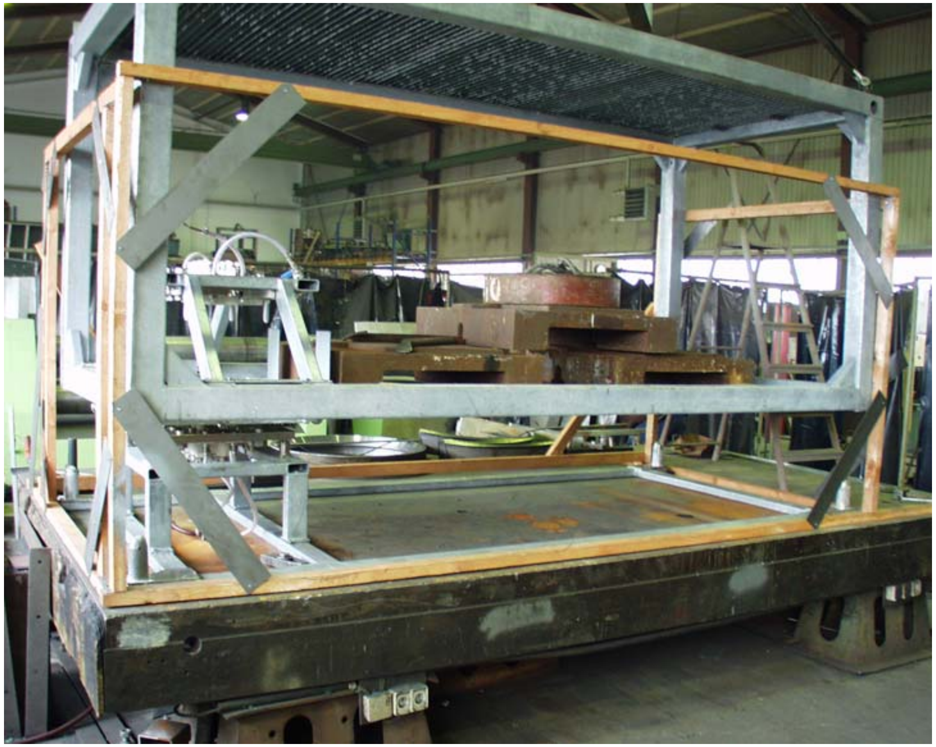
Virtual reality



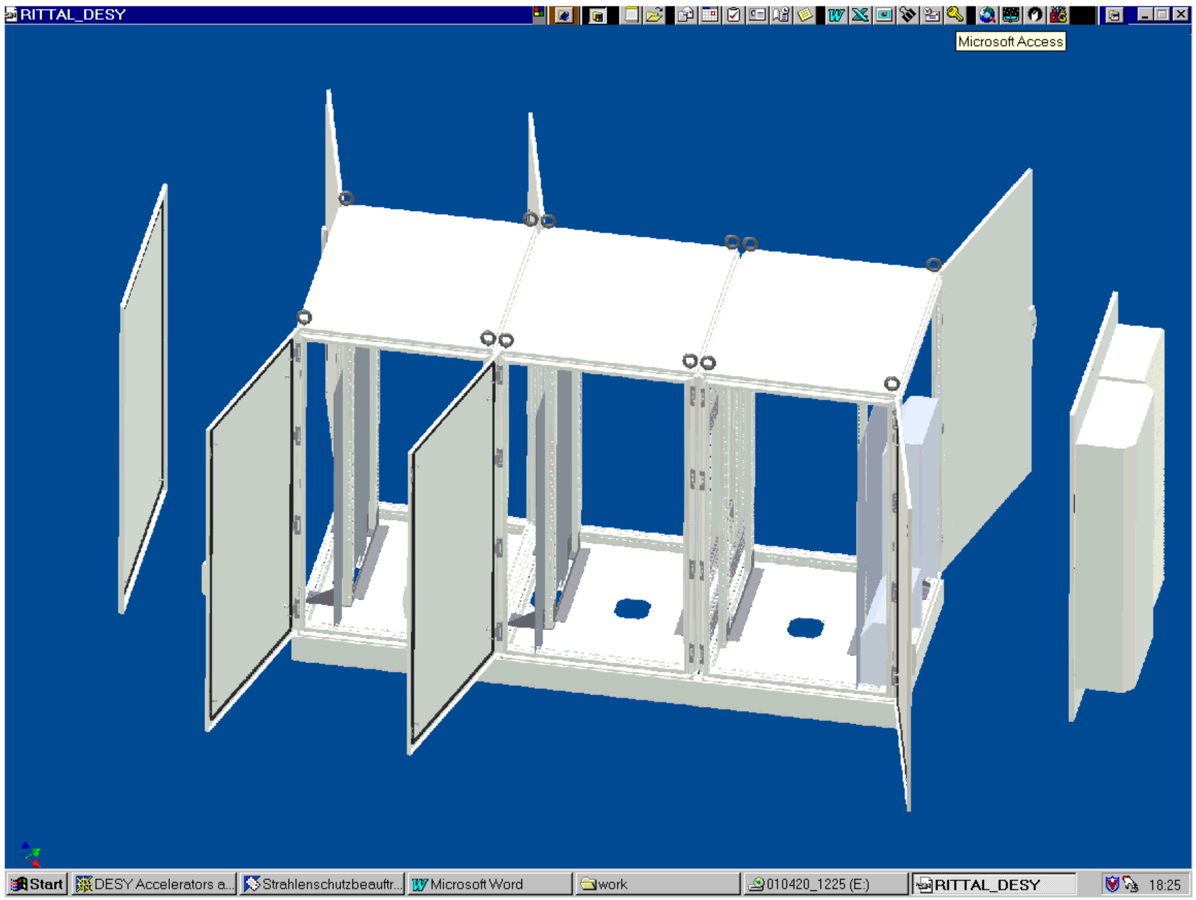
Reality

Hans-Jörg Eckoldt

Container during acceptance test



Electronic racks



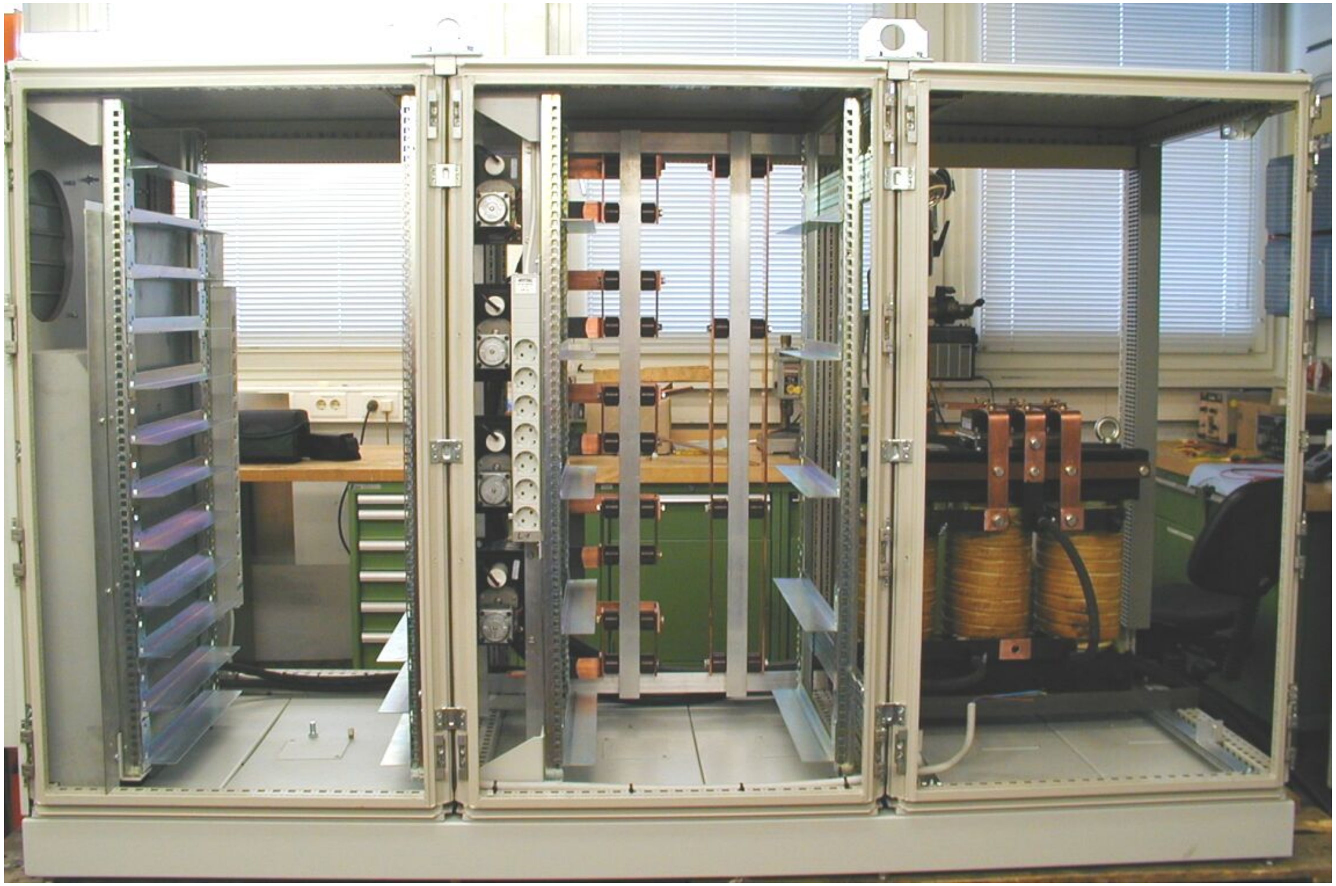
Hans-Jörg Eckoldt

Docking system
(400V, DC 400A, Interlock, BNC, water connections)

Docking system

Hans-Jörg Eckoldt

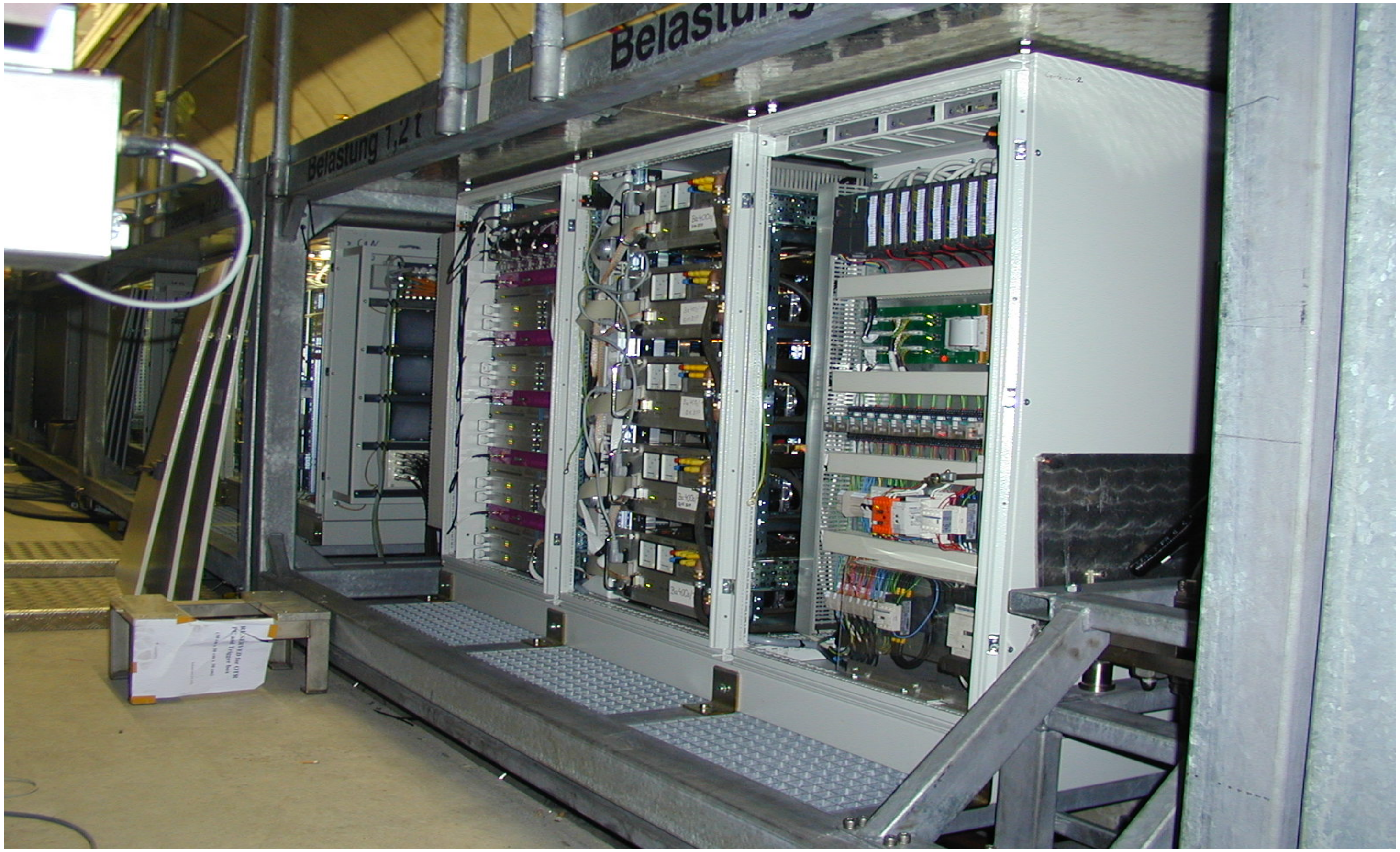
Internal construction of the racks



Container installation

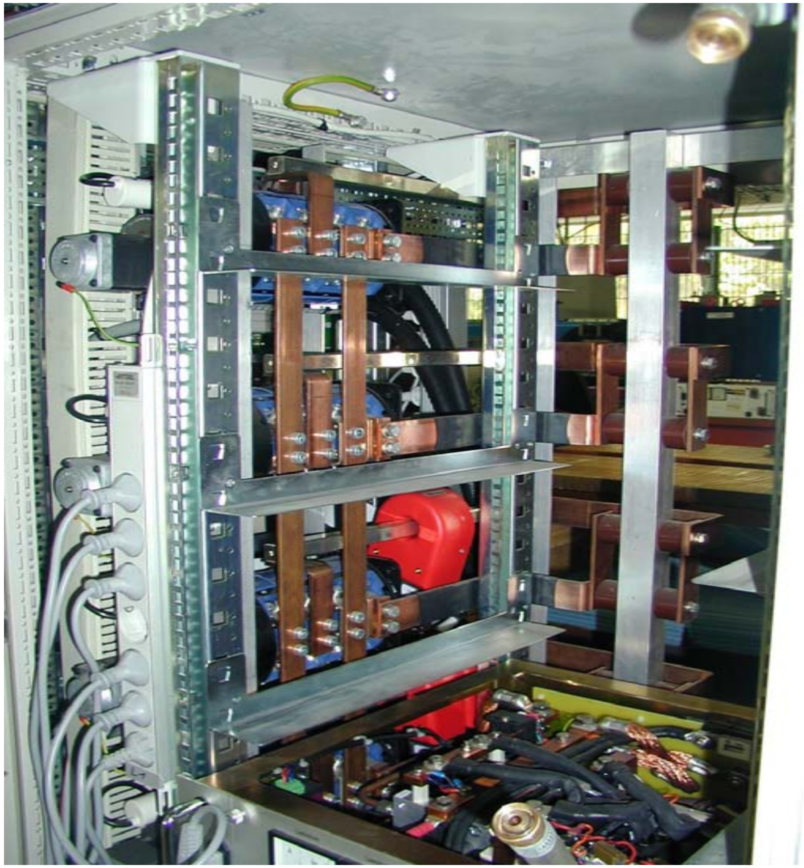
Hans-Jörg Eckoldt

Container in Tunnel



Hans-Jörg Eckoldt

Redundancy system

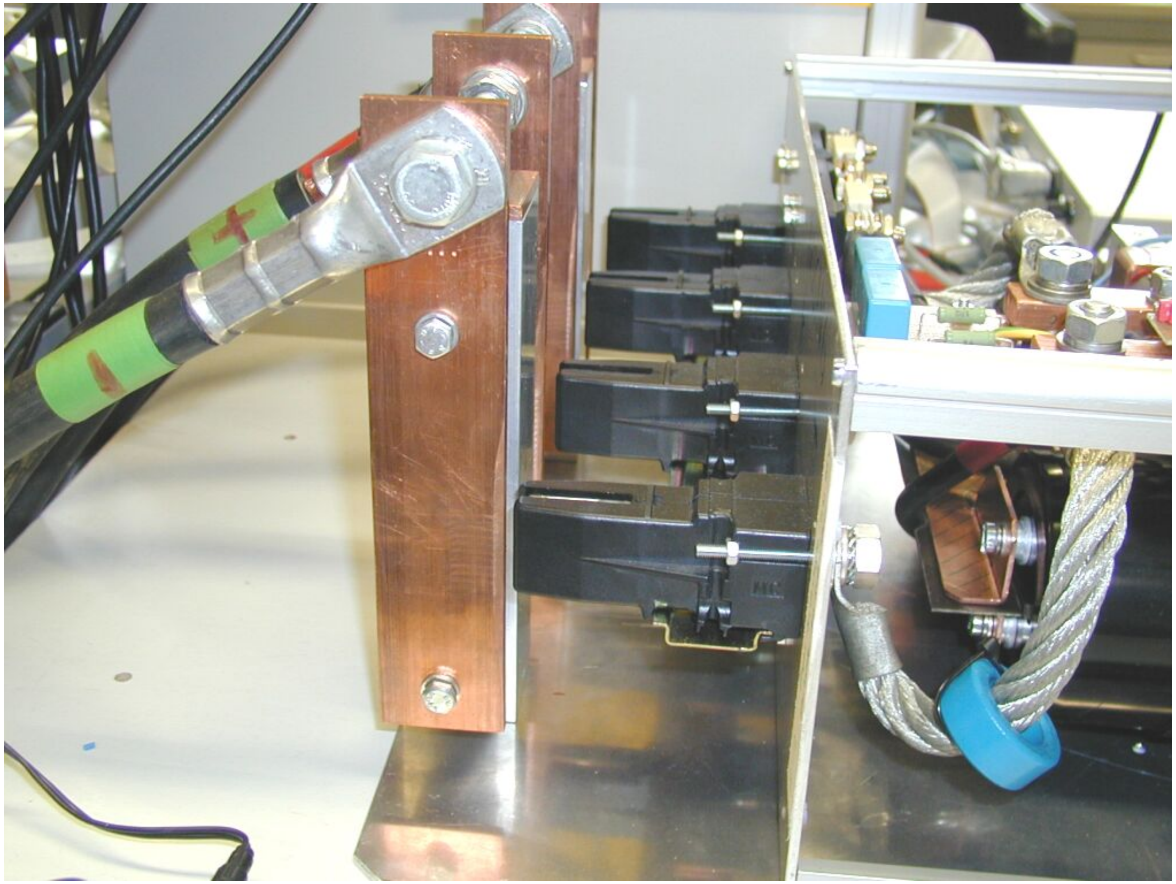


Hans-Jörg Eckoldt

New Buck converter power part
400 A, 60 V

Hans-Jörg Eckoldt

New Buck converter power part



Hans-Jörg Eckoldt

New Power Supply for superconducting magnets +/- 100,A, +/- 10 V

developement by N. Heidbrook

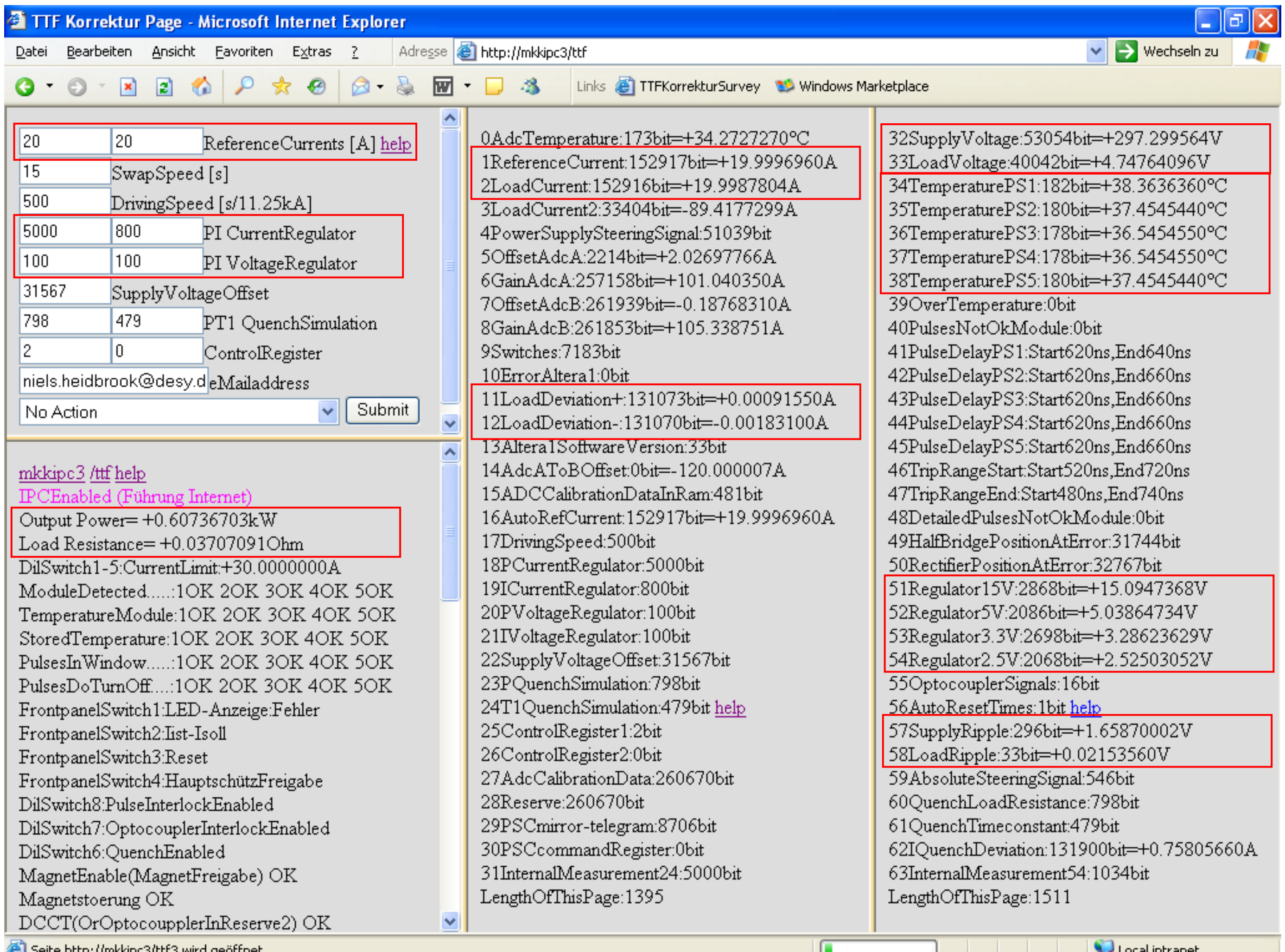
- Internet Access for remote diagnosis
- CAN bus interface to the control system
- 24 bit resolution of ADC, 18 bit accuracy
- Self calibrating for high precision
- Self cable check for commissioning
- Simulation of magnet impedance for quench protection
- **High redundant power part (5 power boards, only 4 are necessary for the full output current)**.

Improvement of reliability

Hans-Jörg Eckoldt

Regulator board web access

Regulation parameters

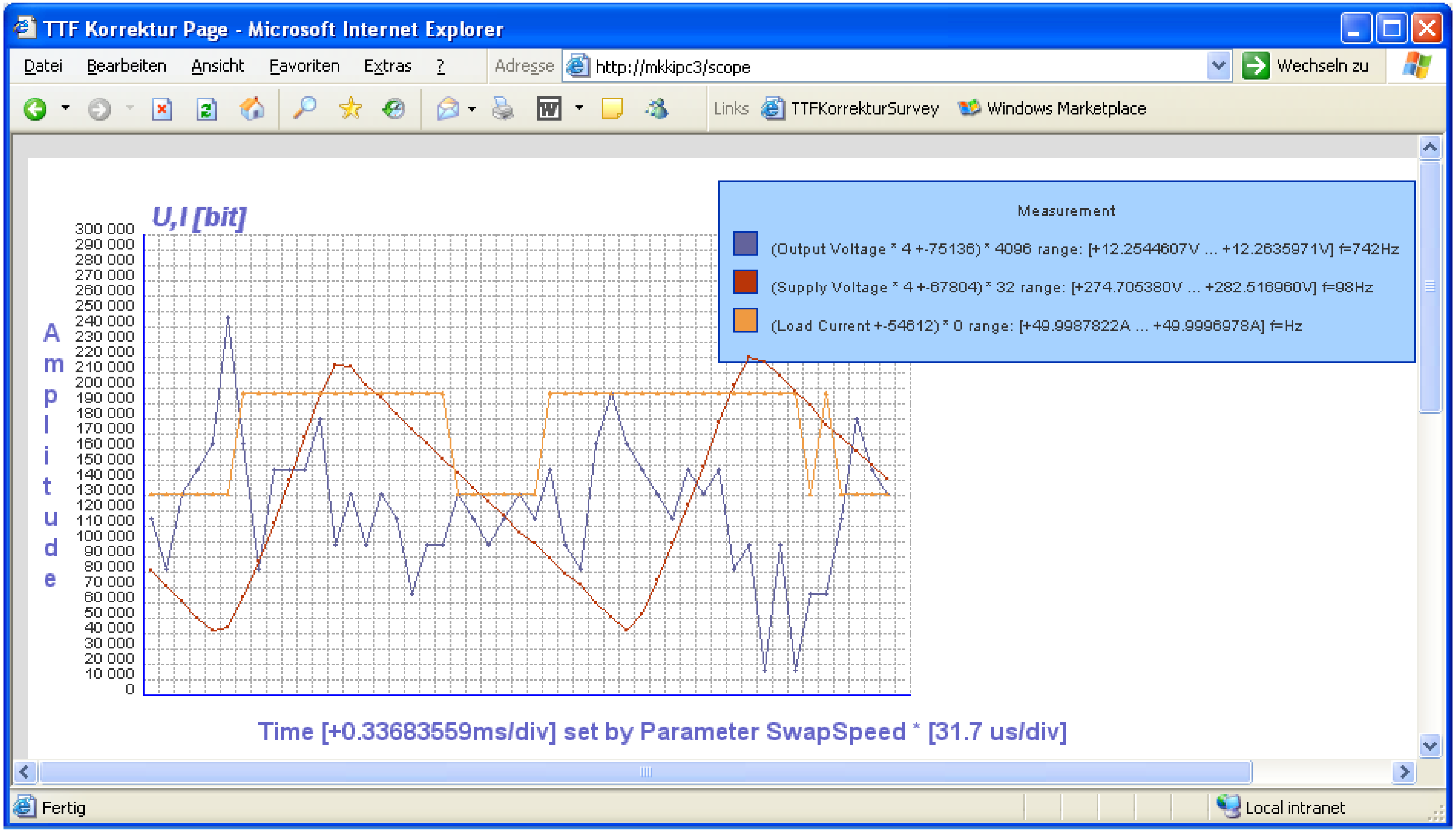


FPGA data

Derived data

Hans-Jörg Eckoldt

Regulator online scope function inside the power supply

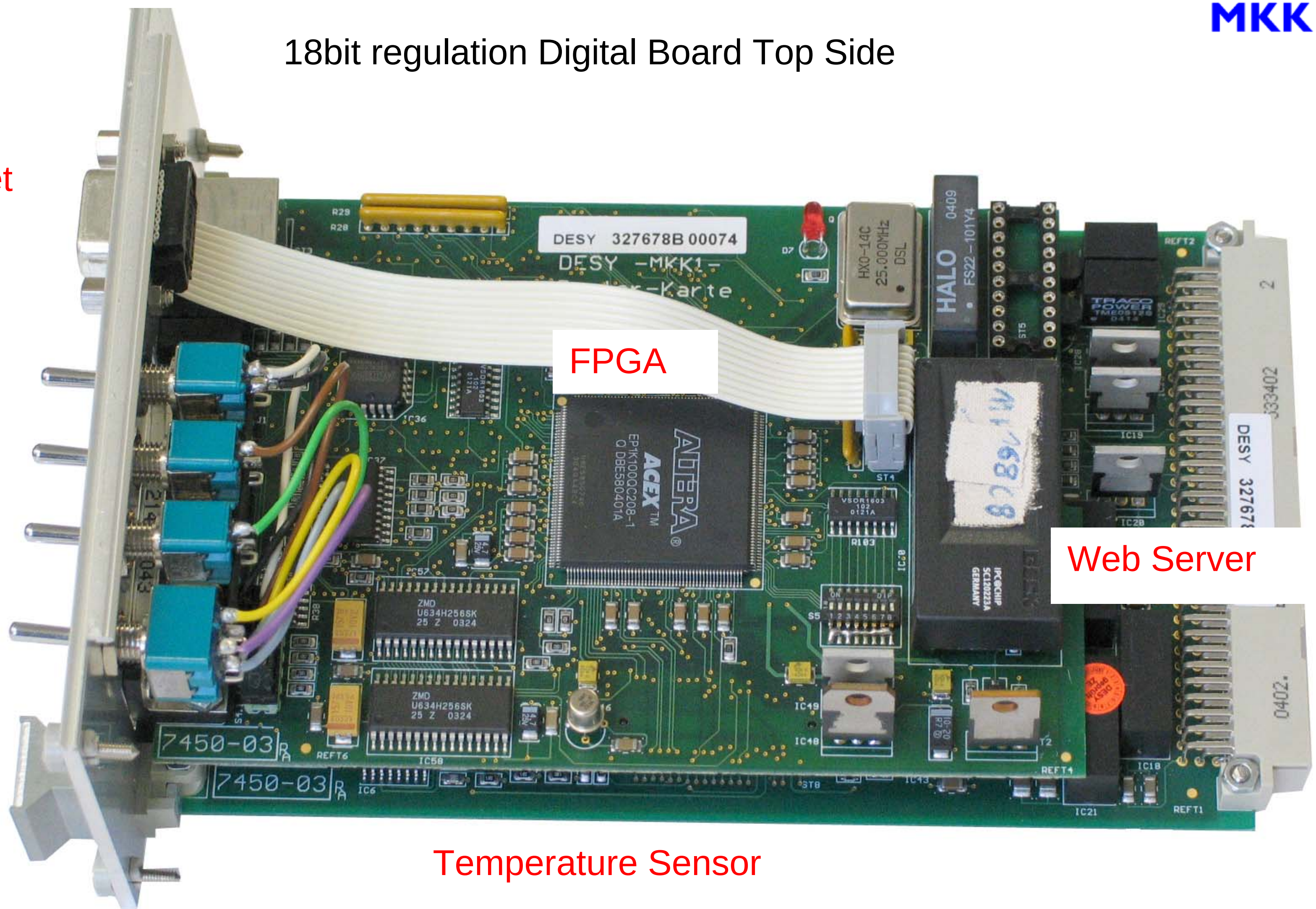


Improvement of reliability

Hans-Jörg Eckoldt

18bit regulation Digital Board Top Side

Ethernet

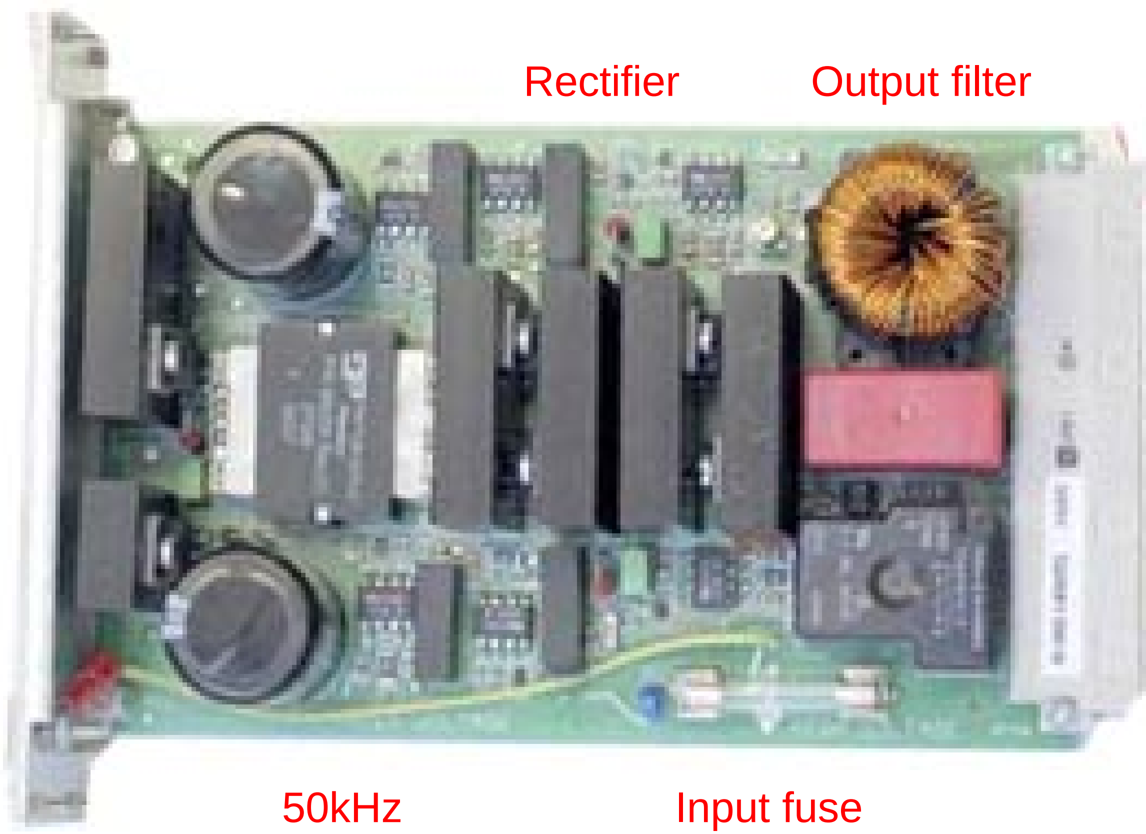


Temperature Sensor

Improvement of reliability

Hans-Jörg Eckoldt

Power Supply Board +/-30A , +/-15V



Rectifier

Output filter

325V DC in

Halfbridge

+/-30A , +/-15V out

Output Relay

50kHz Transformer

Input fuse

Improvement of reliability

Hans-Jörg Eckoldt

Power Supply +-120A , +-15V

DCCT

PSC Remote Control

Digital Regulator

5 Redundant Power Supply Modules +/-30A , +/-15V each

Improvement of reliability

Hans-Jörg Eckoldt

Power Supply +-120A , +-15V

PC104
CAN bus
to Ethernet
controller

Regulator
Ethernet
Connection

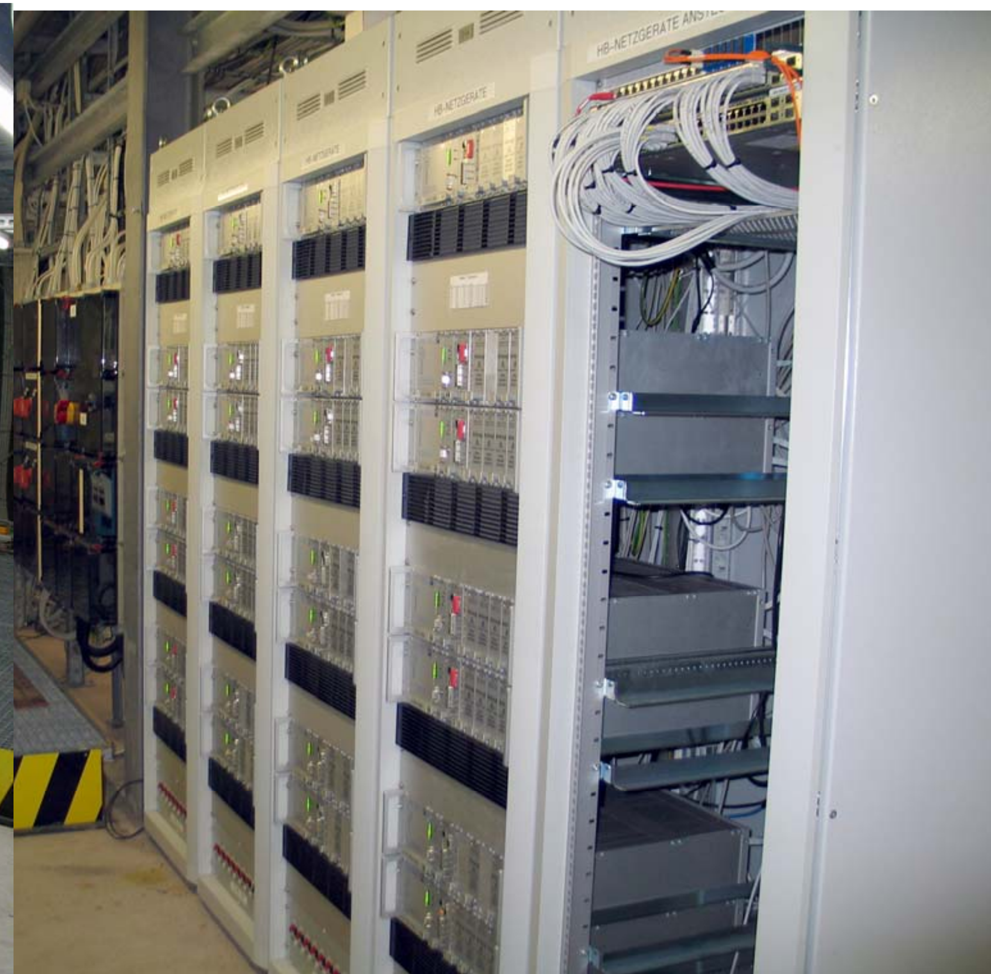
230V AC in

+/-120A , +/-15V out

Improvement of reliability

Hans-Jörg Eckoldt

Installation in FLASH

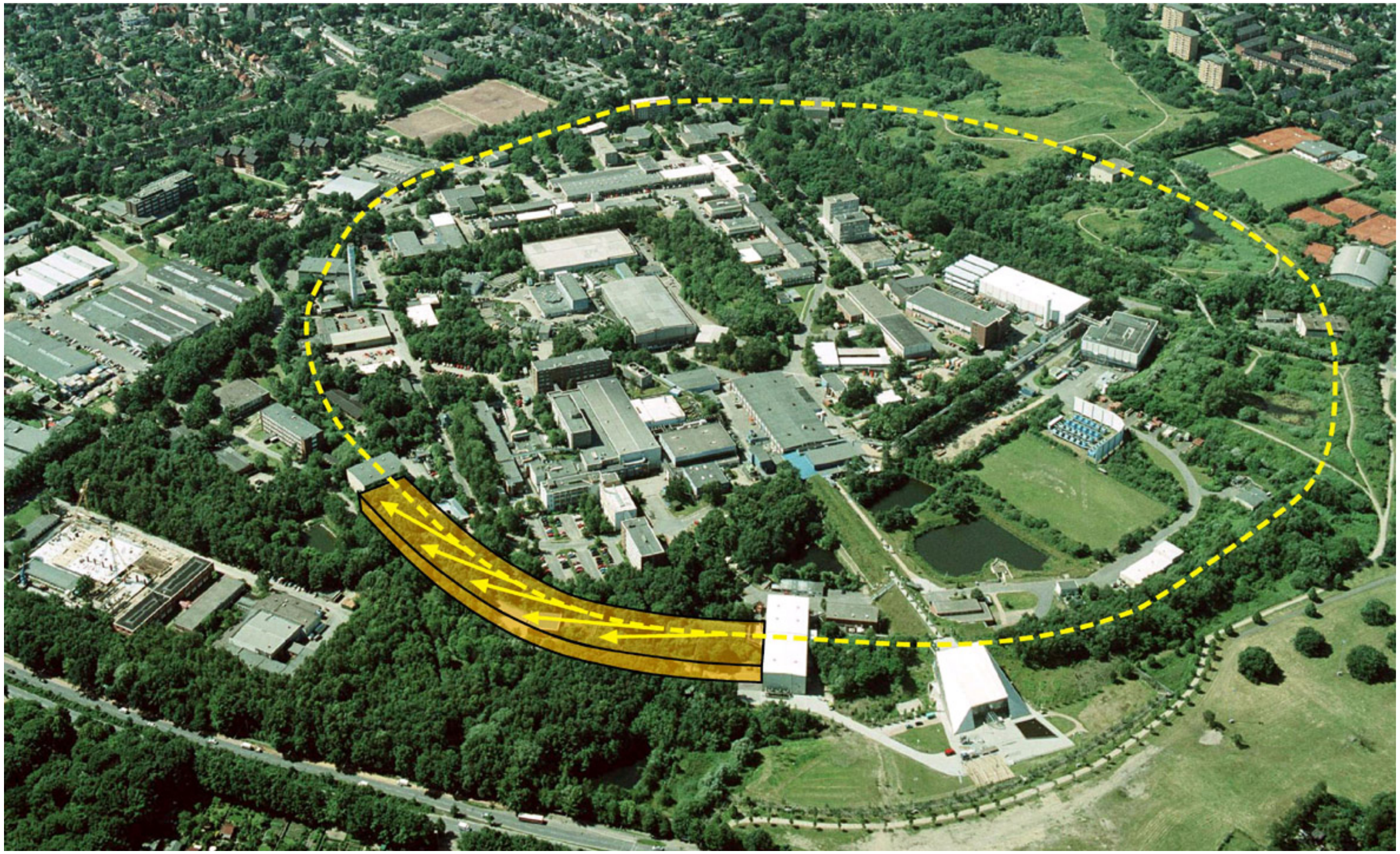


Future Projects
PETRA III

- Synchrotron Radiation Source
- Petra is no longer preaccelerator for HERA which has been shut down in 2007
- Start Construction middle 2007
- Construction time 1 year
- Commissioning in autumns 2008

Hans-Jörg Eckoldt

PETRA III



Hans-Jörg Eckoldt

PETRA Tunnel

Hans-Jörg Eckoldt

Power supplies for PETRA

- For Petra the demand for the reliability is very high.
- There was a time of 15 min of max. downtime after a failure was given.

Hans-Jörg Eckoldt

Overall reliability of power supplies

- The sum of all power supplies

$$MTTF = \frac{1}{\left(\frac{1}{197hrs} + \frac{1}{1111hrs} + \frac{1}{2500hrs}\right)} = 157Hrs$$

Redundancy concept

Required time to be back into operation after failure

⇒ **max. 15 min**

Time to reach the hall + repair time exceeds this time

⇒ **a redundancy system is required**

The PS will equipped with magnetic holding contactors to disconnect the broken PS and reconnect the spare supply

Hans-Jörg Eckoldt

Redundancy system (2)

- For a group of power supplies a spare power supply will be installed.
- In case of failure the shift crew detects the failure.

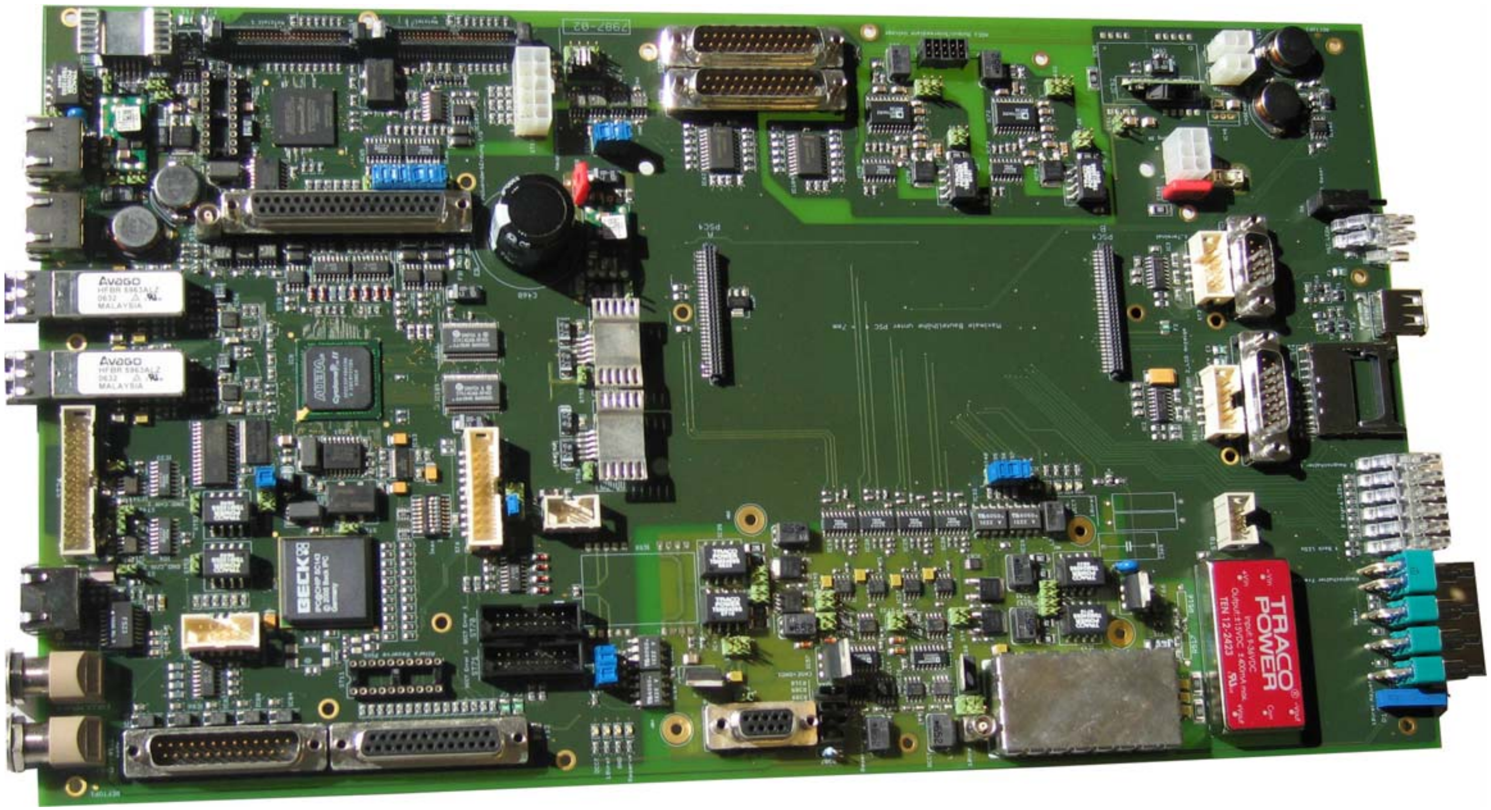
  $\Rightarrow$ control system generates an alarm.
- The shift crew tries to reset the power supply.

  $\Rightarrow$ If not successful, switch over to the spare PS.

- Within few minutes the machine can restart to operate.

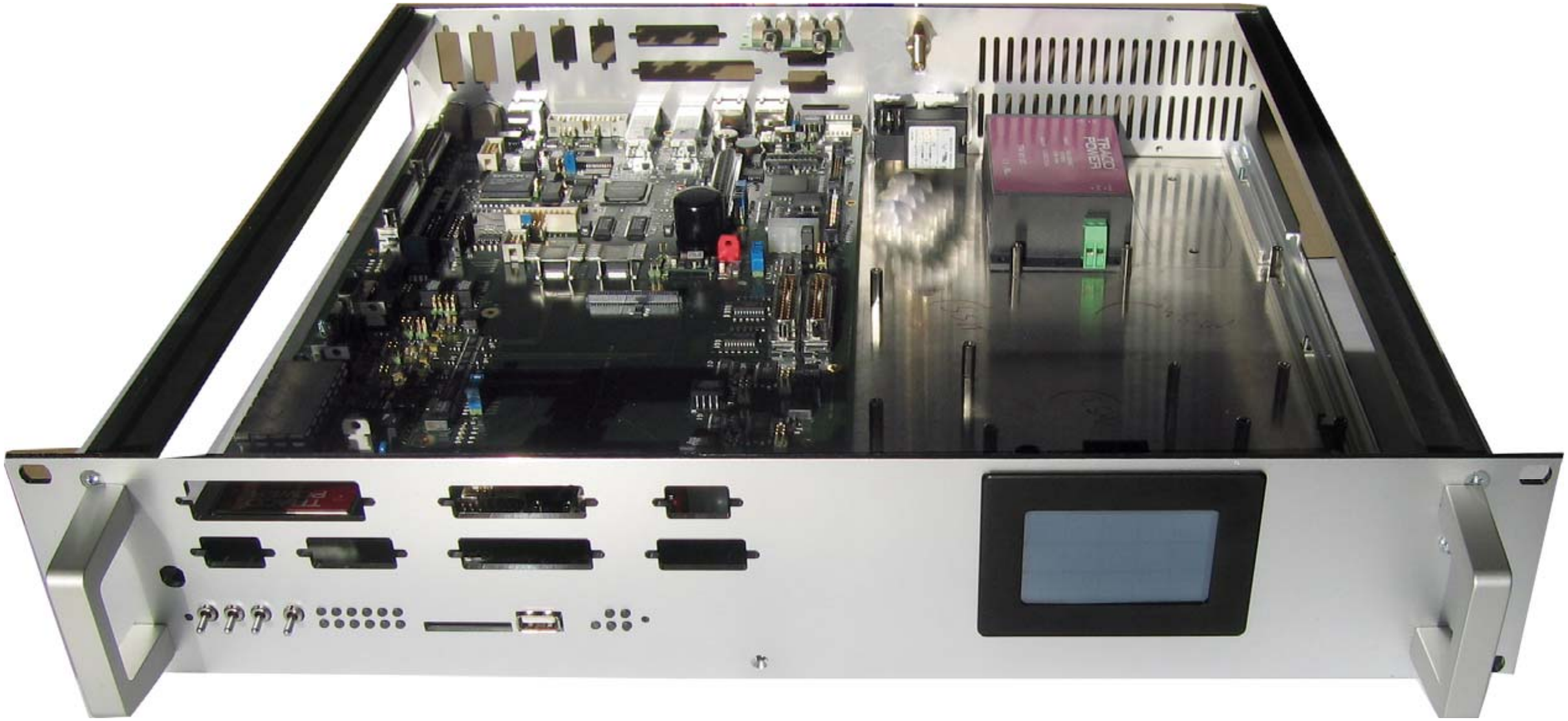
Hans-Jörg Eckoldt

Digital regulation card

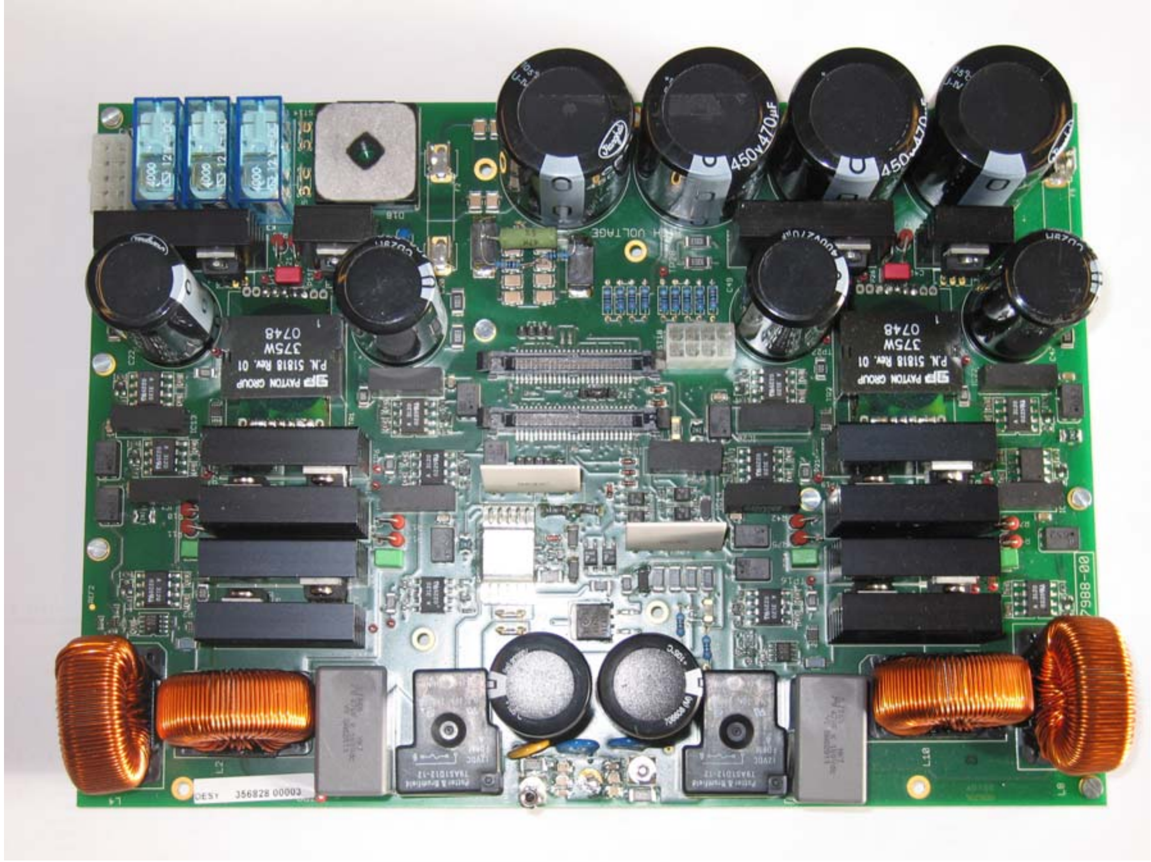


Hans-Jörg Eckoldt

Regulation chassis (prototype)



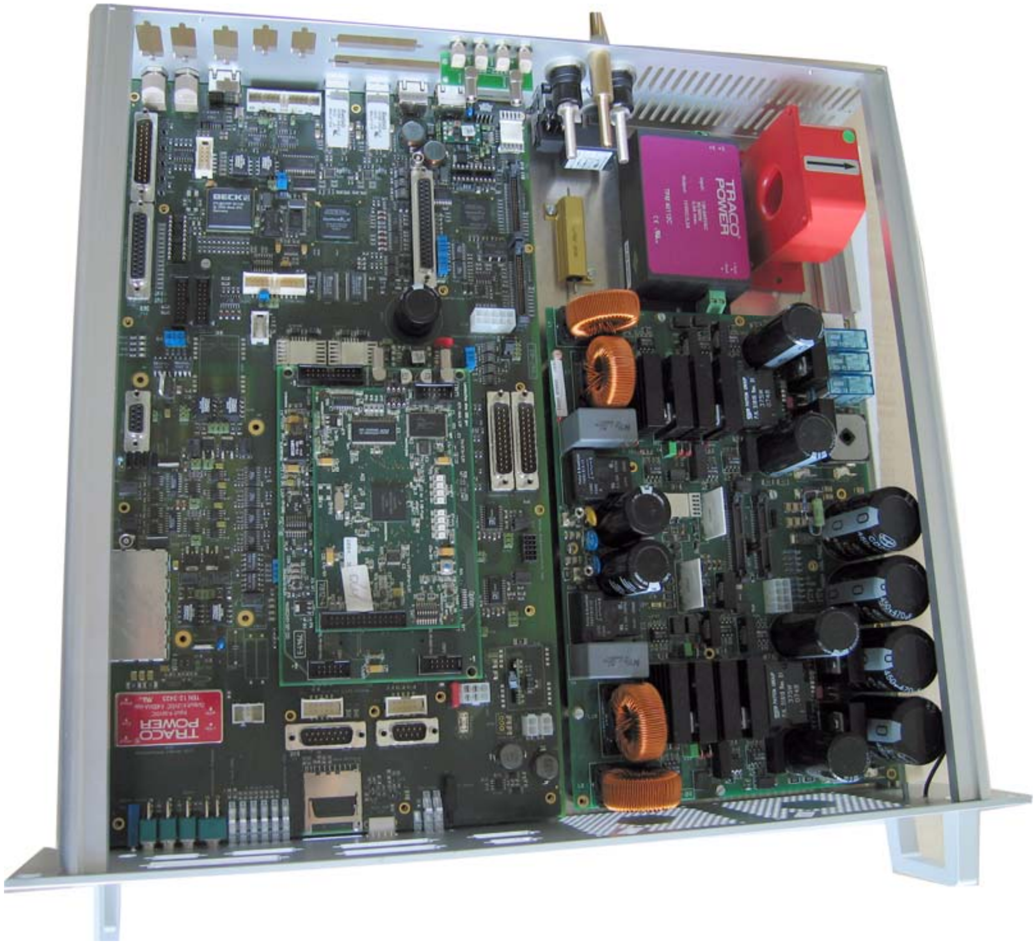
Corrector power card
5A/60V or 10 A/40V



Redundant power part
(over dimensioning
hot spare)

Hans-Jörg Eckoldt

Corrector Supply without cabling

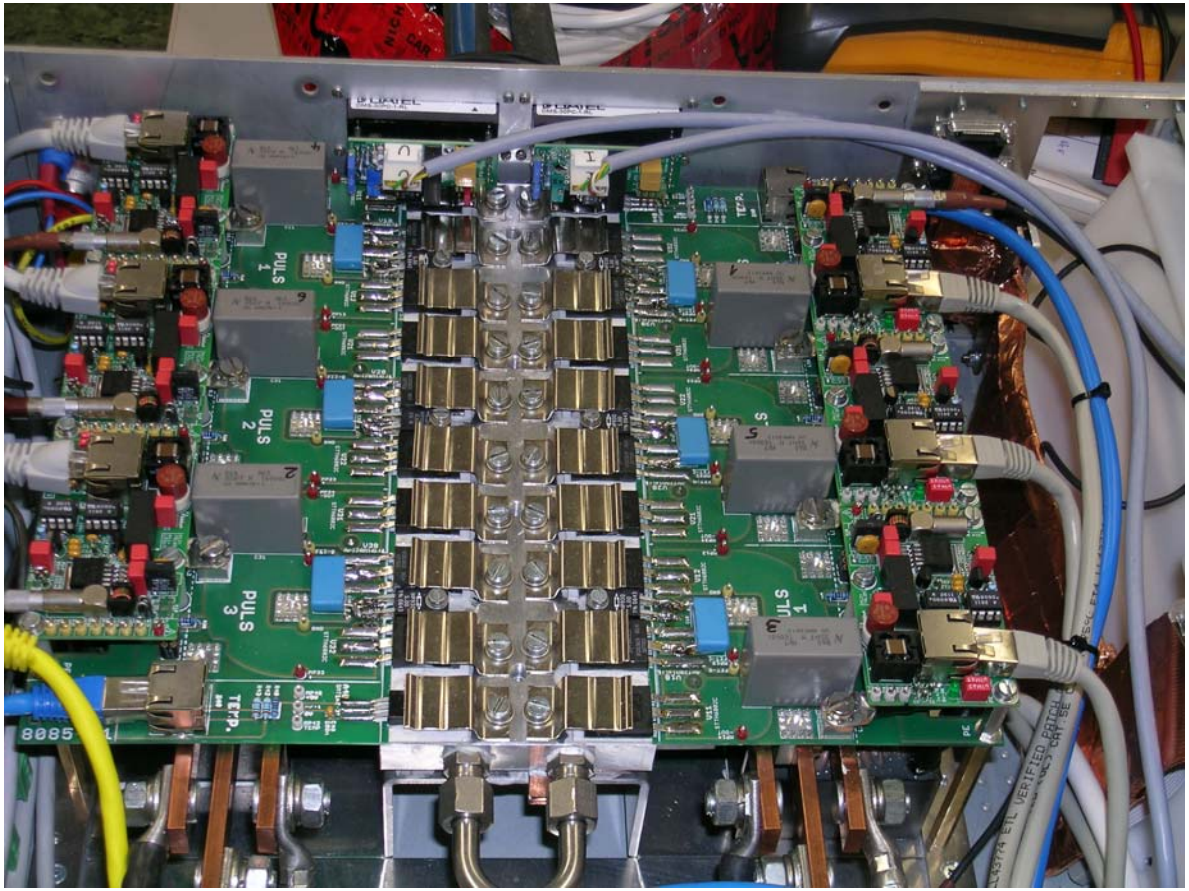


Corrector power supply

200 A Chopper PETRA III

- Here we have a mix of overrating and hot spares
  - 6 bridges of 50 A in parallel
  - The regulation can instantaneously commutate the current from any broken switch to the remaining briges

200 A Switched Mode Prototype



200 A Connectors