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

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1. POPCA Workshop Trieste

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Structure

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

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Ingredients for improvement of reliability

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

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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

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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

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



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Chopper in HERA



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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

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Regulation electronic

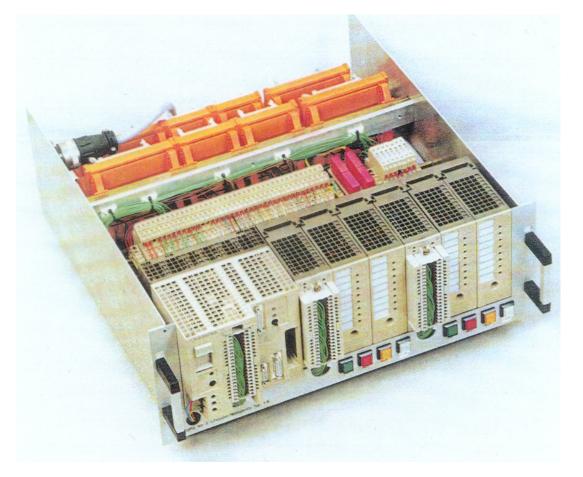


- DAC for 16 or 18 bit
- cascade control with voltage sub loop
- trip for over current and mal function

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Programmable Logic PLC

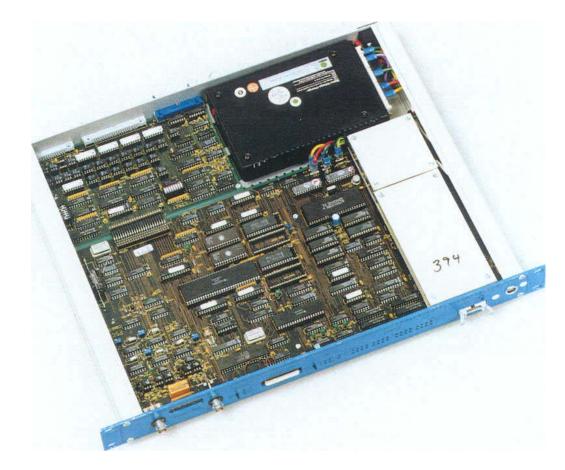


- Protection against over current and over voltage
- Supervision of technical interlocks
- Industrial standard
- Local and remote control

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Power Supply Controller (PSC)

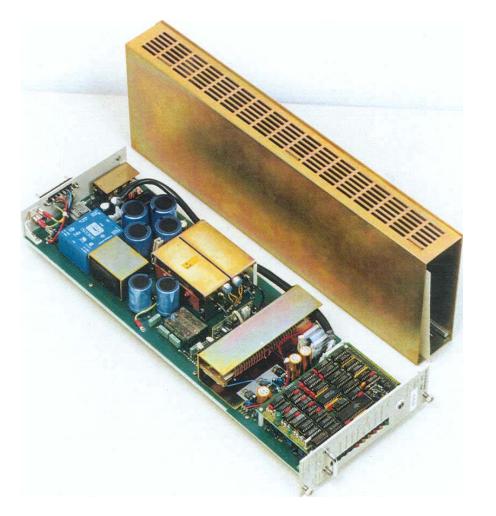


- Interface between power supply and control system
- commands on/off, reset, etc.
- reference current, 16 or 18 bit
- actual value current via DVM
- status and alarms
- 700 units installed

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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

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Strategies developed for TESLA, TTF-VUVFEL, XFEL

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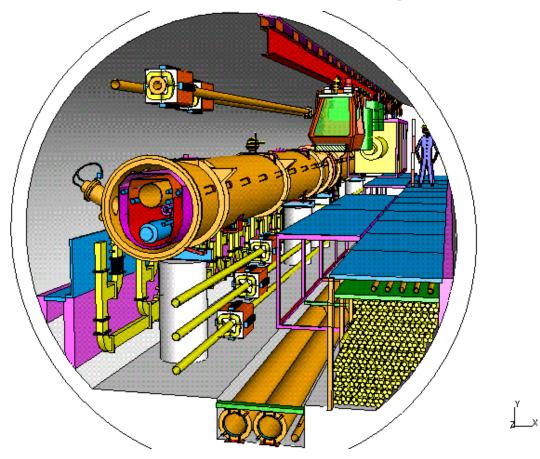
TESLA

- 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

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View into TESLA tunnel (old design)



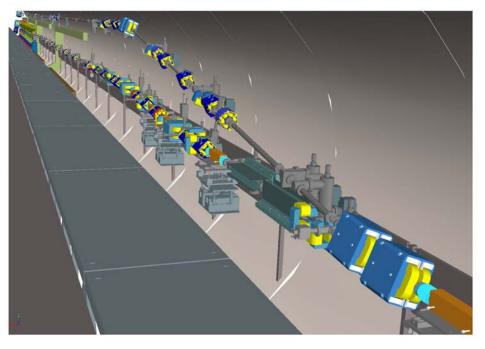
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Flash Tunnel FLASH started a TESLA Test Facility (TTF)

Virtual reality

Reality

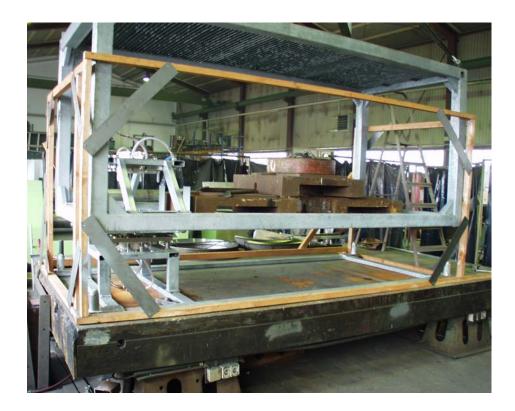




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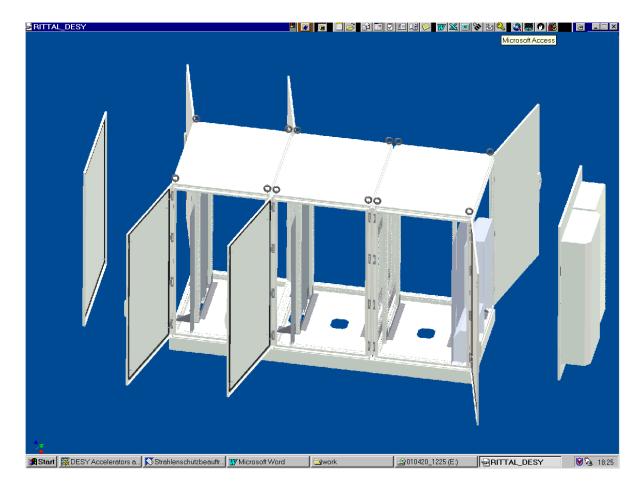
Container during acceptance test



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Electronic racks



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





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Docking system

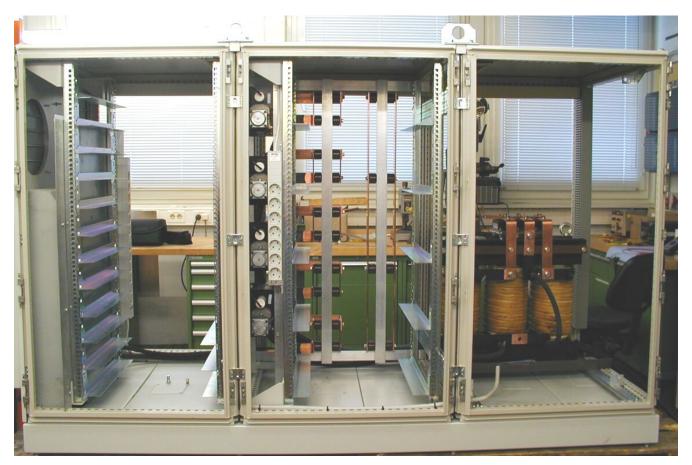




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Internal construction of the racks



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Container installation





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Container in Tunnel

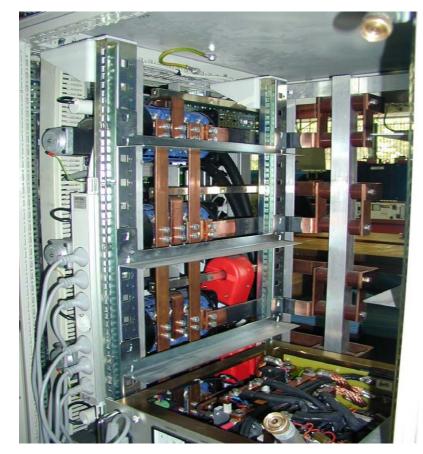


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Redundancy system





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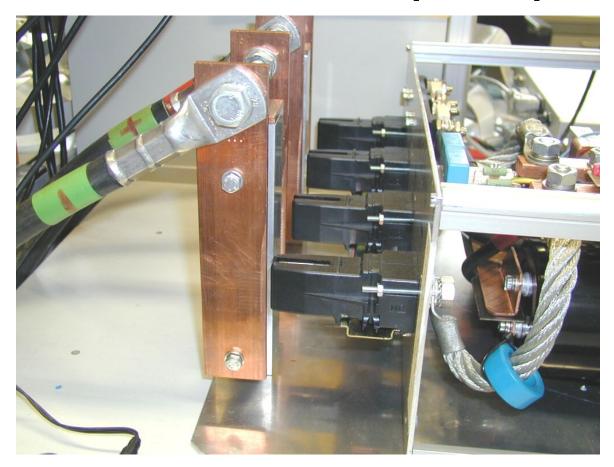
New Buck converter power part 400 A, 60 V



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New Buck converter power part



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

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Regulator board web access

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20 20 ReferenceCurrents [A] help 15 SwapSpeed [s] 500 DrivingSpeed [s/11.25kA] 5000 800 PI CurrentRegulator 100 100 PI VoltageRegulator 31567 SupplyVoltageOffset 798 479 PT1 QuenchSimulation 2 0 ControlRegister niels.heidbrook@desy.deMailaddress Submit	0AdcTemperature:173bit=+34.2727270°C 1ReferenceCurrent:152917bit=+19.9996960A 2LoadCurrent:152916bit=+19.9987804A 3LoadCurrent:33404bit=-89.4177299A 4PowerSupplySteeringSignal.51039bit 5OffsetAdcA:2214bit=+2.02697766A 6GainAdcA:257158bit=+101.040350A 7OffsetAdcB:261939bit=-0.18768310A 8GainAdcB:261853bit=+105.338751A 9Switches:7183bit 10ErrorAltera1:0bit 11LoadDeviation+:131073bit=+0.00091550A 12LoadDeviation-:131070bit=-0.00183100A	32SupplyVoltage:53054bit=+297.299564V 33LoadVoltage:40042bit=+4.74764096V 34TemperaturePS1:182bit=+38.3636360°C 35TemperaturePS2:180bit=+37.454540°C 36TemperaturePS3:178bit=+36.5454550°C 37TemperaturePS5:180bit=+37.454540°C 38TemperaturePS5:180bit=+37.454540°C 39OverTemperature:0bit 40PulseSNotOkModule:0bit 41PulseDelayPS1:Start620ns,End640ns 42PulseDelayPS3:Start620ns,End660ns 44PulseDelayPS4:Start620ns,End660ns	
mkkipc3 /ttf help IP CEnabled (Führung Internet) Output Power= +0.60736703kW Load Resistance= +0.037070910hm DiSwitch1-5:CurrentLimit+30.0000000A ModuleDetected:10K 20K 30K 40K 50K TemperatureModule:10K 20K 30K 40K 50K StoredTemperature:10K 20K 30K 40K 50K PulsesInWindow:10K 20K 30K 40K 50K PulsesInWindow:10K 20K 30K 40K 50K PulsesDoTurnOff:10K 20K 30K 40K 50K FrontpanelSwitch1:LED-Anzeige:Fehler FrontpanelSwitch2:Ist-Isoll FrontpanelSwitch3:Reset FrontpanelSwitch3:Reset FrontpanelSwitch3:Reset DilSwitch8:PulseInterlockEnabled DilSwitch6:QuenchEnabled MagnetEnable(MagnetFreigabe) 0K MagnetStoerung 0K	13Lboadbeviator:1510706i=-0.00185100A 13Altera1SoftwareVersion:33bit 14AdcAToBOffset:0bit=-120.000007A 15ADCCalibrationDataInRam:481bit 16AutoRefCurrent:152917bit=+19.9996960A 17DrivingSpeed:500bit 18PCurrentRegulator:5000bit 19ICurrentRegulator:5000bit 19ICurrentRegulator:100bit 20PVoltageRegulator:100bit 21IVoltageRegulator:100bit 23SupplyVoltageOffset:31567bit 23PQuenchSimulation:798bit 24T1QuenchSimulation:798bit 24T1QuenchSimulation:798bit 25ControIRegister1:2bit 26ControIRegister2:0bit 27AdcCalibrationData:260670bit 29PSCmirror-telegram:8706bit 30PSCcommandRegister:0bit 31InternalMeasurement24:5000bit LengthOfThisPage:1395	44PuseDelayPS4:Start620ns,End660ns 45PulseDelayPS5:Start620ns,End720ns 47TripRangeEnd:Start480ns,End740ns 48DetailedPulsesNotOkMo.dule:0bit 49HalfBridgePositionAtError:31744bit 50RectifierPositionAtError:32767bit 51Regulator15V:2868bit=+15.0947368V 52Regulator5V:2086bit=+5.03864734V 53Regulator3.3V:2698bit=+3.28623629V 54Regulator2.5V:2068bit=+2.52503052V 55OptocouplerSignals:16bit 56AutoResetTimes:1bit.help 57SupJyRipple:296bit=+1.65870002V 58LoadRipple:33bit=+0.02153560V 59AbsoluteSteeringSignal:546bit 60QuenchLoadResistance:798bit 61QuenchDeviation:131900bit=+0.75805660A 63InternalMeasurement54:1034bit LengthOfThisPage:1511	FPC data

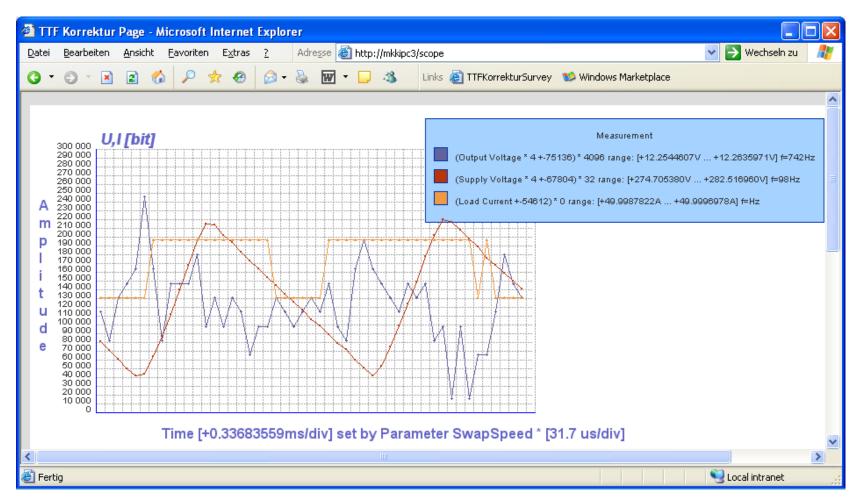
Regulation parameters

Derived data

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Regulator online scope function inside the power supply



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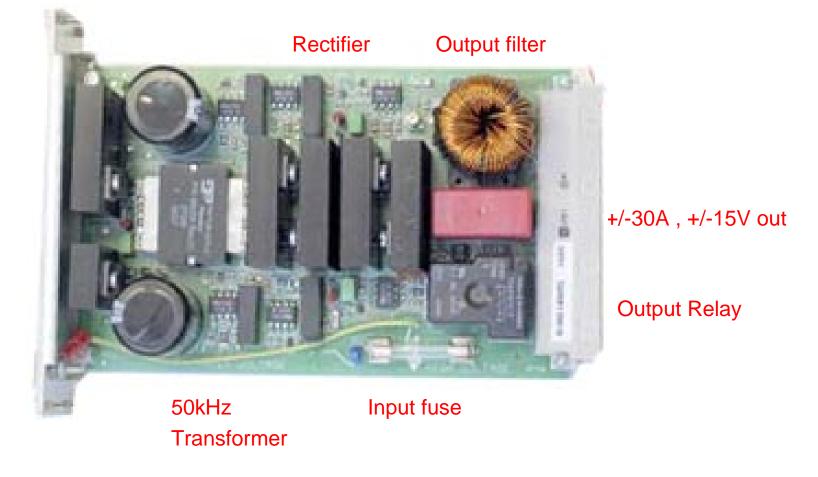


Temperature Sensor

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



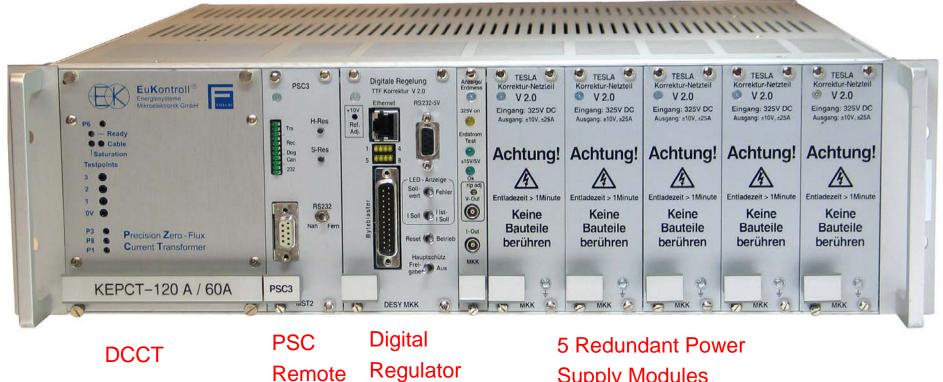
325V DC in

Halfbridge

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Power Supply +-120A , +-15V



Control

Supply Modules +/-30A , +/-15V each

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Power Supply +-120A , +-15V



PC104 CAN bus to Ethernet controller Regulator Ethernet Connection

230V AC in

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

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Installation in FLASH



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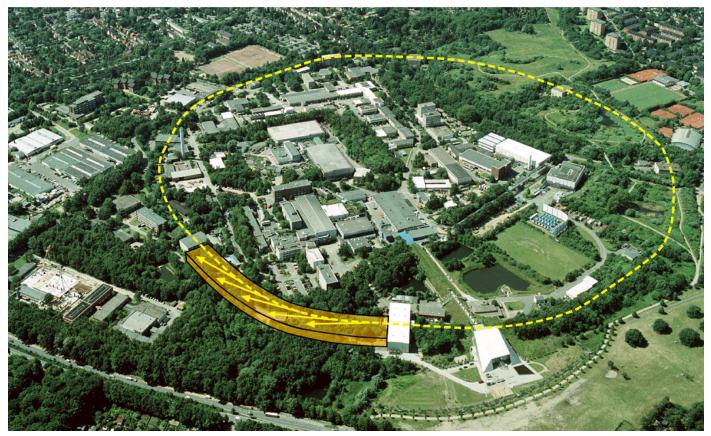
Future Projects PETRA III

- 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

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PETRA III



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PETRA Tunnel



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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.

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Overall reliability of power supplies

• The sum of all power supplies

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

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Redundancy concept Required time to be back into operation after failure \Rightarrow max. 15 min

Time to reach the hall + repair time exceeds this time

\Rightarrow a redundancy system is required

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

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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.
 ⇒ control system generates an alarm.
- The shift crew tries to reset the power supply.
 ⇒ If not successful, switch over to the spare PS.
- Within few minutes the machine can restart to operate.

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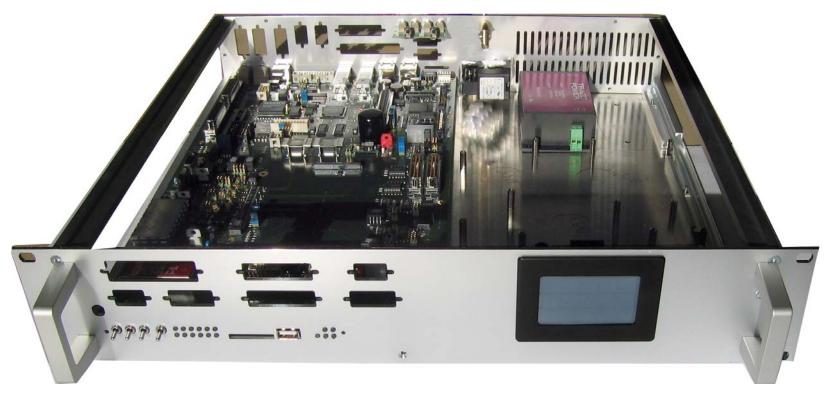
Digital regulation card



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Regulation chassis (prototype)



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DESY MKK

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

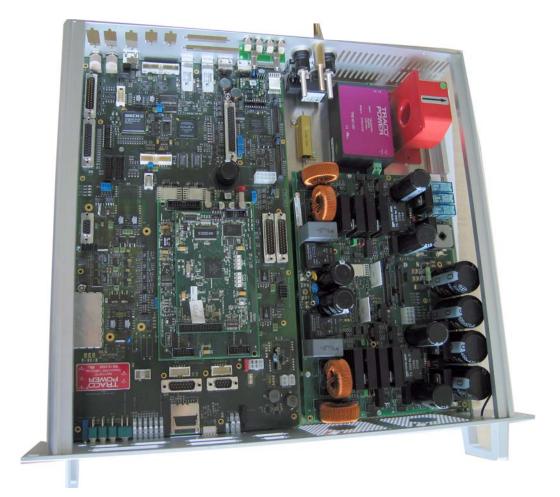


Redundant power part (over dimensioning hot spare)

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Corrector Supply without cabling



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Corrector power supply



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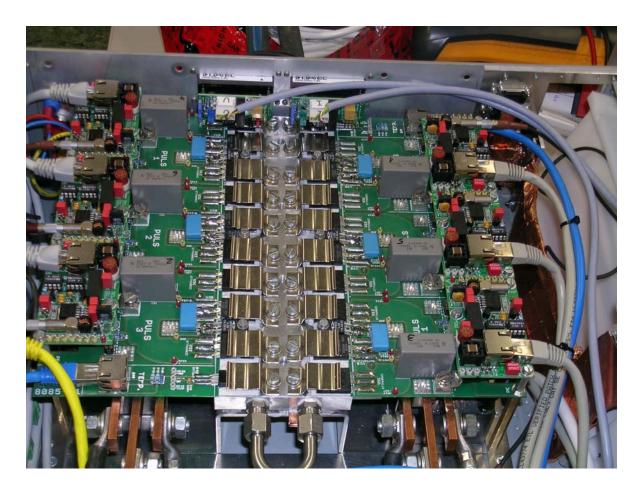
200 A Chopper PETRA III

- 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

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200 A Switched Mode Prototype



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200 A Connectors

