

Status of Power Converters of FAIR

- FAIR and GSI *a short introduction*
- Overview on the Needs of FAIR with respect to power converters
- Status of Work

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FAIR and GSI *a short introduction*

FAIR is:

- a scientific project
- a technical project

and

- a financial project
- a political project

Gesellschaft für SChwerionenforschung

National research facility:

GSI

Heavy Ion Research Facility

Associates: State of Hessen 10%

Federal Republic of Germany (90%)



Link: http://www.gsi.de/portrait/ueberblick_e.html

Facility for Antiproton and Ion Research

International research facility: **FAIR**

Associates: Germany 75% (65% / 10%; Federal / Hessen)

International partners 25%



Link: http://www.gsi.de/fair/index_e.html

1st Workshop on Power Converters for Particle Accelerators (POCPA)

ELETTRA – Trieste/Italy, 19th-21st May ,2008

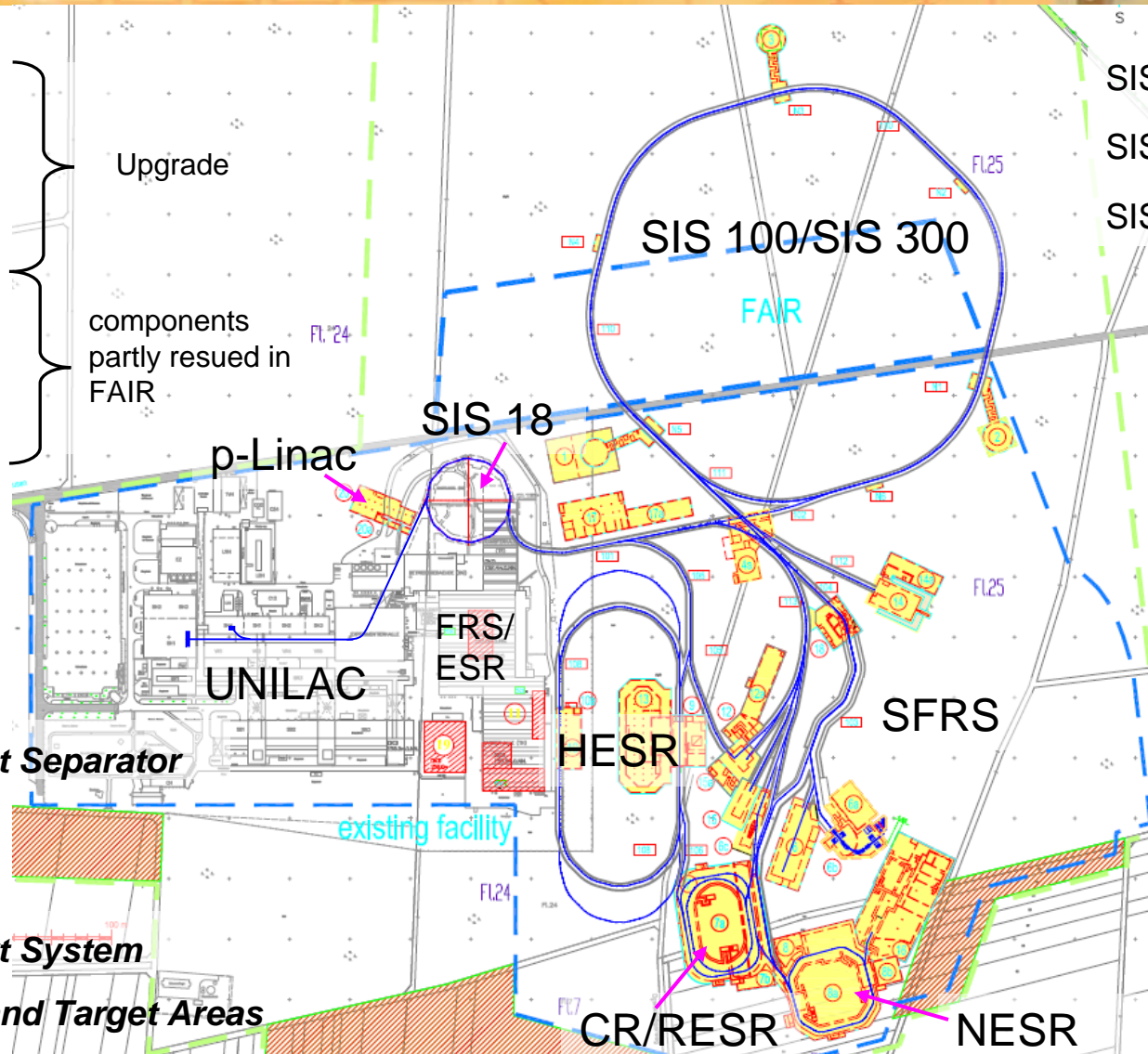


GSI:

- UNILAC
- Transfer Line
- SIS 18
- ESR
- FRS
- Beam lines

FAIR:

- Proton Linac
- SIS 100
- SIS 300
- Super Fragment Separator
- pbar
- Storage Rings
- Beam Transport System
- Experimental and Target Areas



The concept of In-Kind-Contributions:

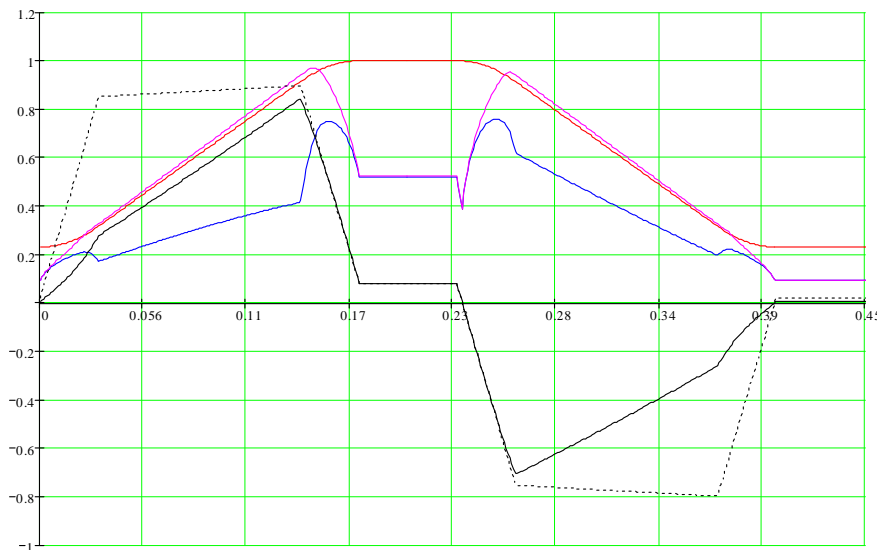
An international partner takes over a work package
in own technical and financial responsibility
according to the functional needs
and basic specifications of the work package
and the costs as listed in the cost book.

Status of Power Converters of FAIR

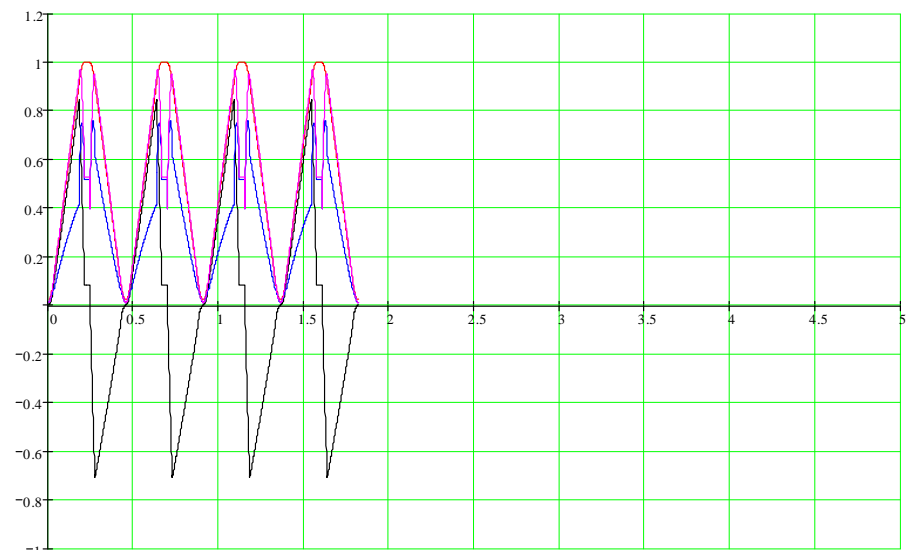
- FAIR and GSI *a short introduction*
- **Overview on the Needs of FAIR with respect to power converters**
 - Upgrade of UNILAC and SIS 18 Power Converters
 - FAIR Power Converters
 - Electrical Power Grid
- **Status of Work**

Upgrade of UNILAC and SIS 18 Power Converters:

SIS 18 Main Dipole Power Converter



SIS 18 Power Cycle 2,65 Hz



SIS 18 Power Cycle 0,2 Hz

$I_{nom} = 3500 \text{ A}$ $P_{nom} = 50 \text{ MW}$ $Q_{nom} = 50 \text{ MVar}$ $S_{nom} = 50 \text{ MVA}$ $U_{norm} = 12 \text{ kV (- - -)}$

FAIR Power Converters :

-Linear Accelerator:

p-Linac

-Synchrotrons:

SIS100, SIS300

-Super Fragment Separator:

SFRS

-Storage Rings :

NESR, RESR, CR, HESR

-Beam Transport System:

13Tm, 18Tm, 100Tm, 300Tm

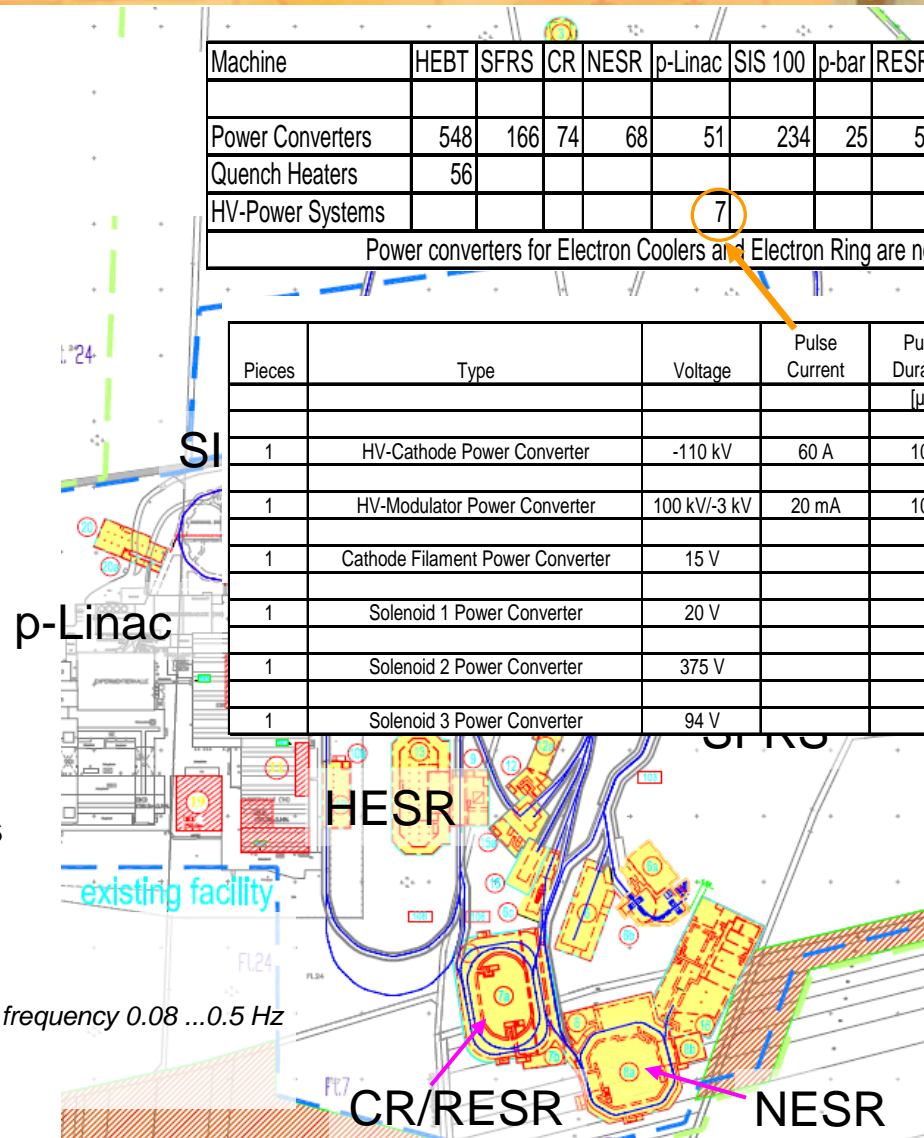
- Experimental and Target Areas

Operation:

- p-Linac: *DC, pulsed*
- Synchrotrons : *ramped, maximum cycling frequency 0.08 ...0.5 Hz*
- Beam Transport : *DC, pulsed, fast pulsed*

| Machine | HEBT | SFRS | CR | NESR | p-Linac | SIS 100 | p-bar | RESR | HESR | SIS300 | Total |
|--------------------------------------------------------------------------|------|------|----|------|---------|---------|-------|------|------|--------|-------|
| Power Converters | 548 | 166 | 74 | 68 | 51 | 234 | 25 | 58 | 141 | 222 | 1587 |
| Quench Heaters | 56 | | | | | | | | | 296 | 352 |
| HV-Power Systems | | | | | 7 | | | | | | 42 |
| Power converters for Electron Coolers and Electron Ring are not included | | | | | | | | | | | |

| Pieces | Type | Voltage | Pulse Current | Pulse Duration [μs] | Pulse Repetition [Hz] | DC Current [A] |
|--------|----------------------------------|--------------|---------------|---------------------|-----------------------|----------------|
| 1 | HV-Cathode Power Converter | -110 kV | 60 A | 100 | 5 | |
| 1 | HV-Modulator Power Converter | 100 kV/-3 kV | 20 mA | 100 | 5 | |
| 1 | Cathode Filament Power Converter | 15 V | | | | 26 |
| 1 | Solenoid 1 Power Converter | 20 V | | | | 20 |
| 1 | Solenoid 2 Power Converter | 375 V | | | | 20 |
| 1 | Solenoid 3 Power Converter | 94 V | | | | 20 |



FAIR Power Converters :

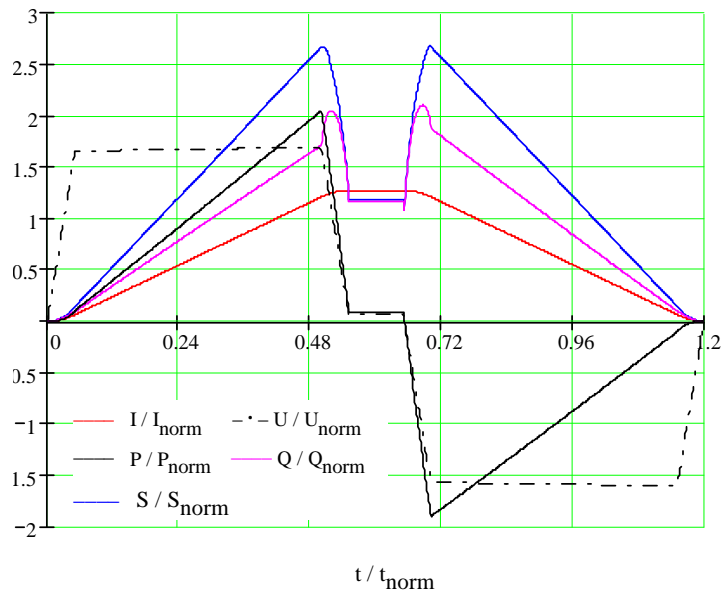
Examples of desired characteristics of supplies :

- High Voltage Supplies : -110 kV , 60A pulsed, t-on =100 μ s, f= 5Hz (p-Linac)
- DC Converters : up to 8930A, 7Vmax , 4V DC, sc, (HEBT)
- DC Converters : up to 17kA , 90V DC , nc, (SIS 100)
- Pulsed Converters : up to 2200A, 460Vmax , 40V DC, tr=320ms , nc, (HEBT)
- Fast Pulsed Converters : 12kA, 630Vmax , t_flat = 5ms, nc, (CR)
- Ramped Converters : Dipole-System, sc , 0.45 Hz, +/- 21MW , 13kA (SIS100)
- Ramped Converters : Dipole-System, sc , 0.08 Hz, +/- 22MW , 8930A (SIS300)

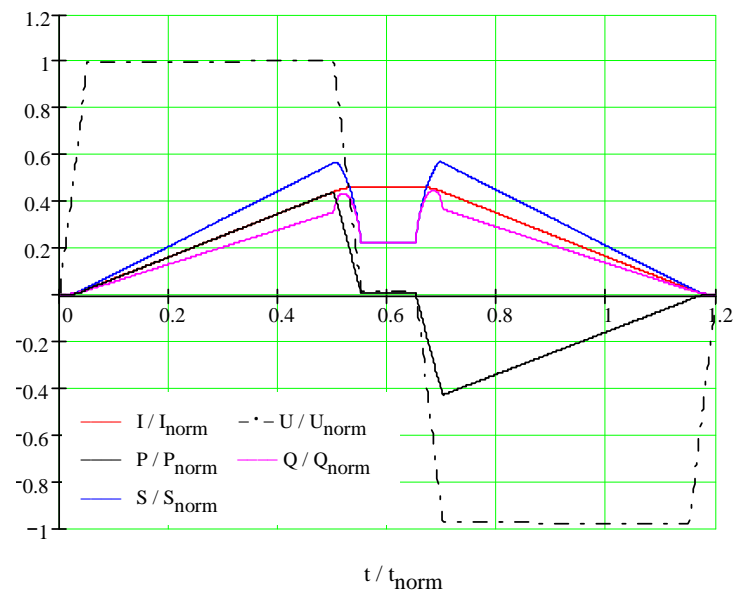
FAIR Power Converters :

Power Requirements with Energy Recovery :

$I_{norm} = 10000 \text{ A}$ $U_{norm} = 1000 \text{ V}$ $t_{norm} = 1 \text{ s}$
 $P_{norm} = 10 \text{ MW}$ $Q_{norm} = 10 \text{ MVA}$ $S_{norm} = 10 \text{ MVA}$



SIS 100 Dipole Power Converter

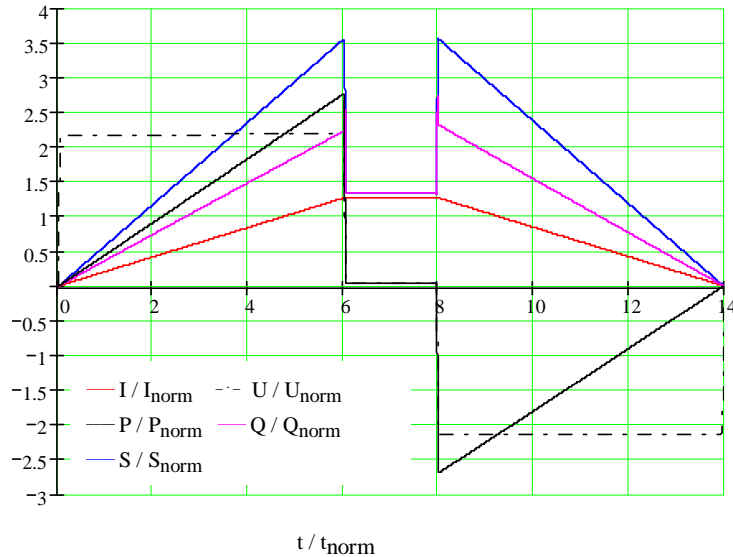


SIS 100 Quadrupole Type I Power Converter

FAIR Power Converters :

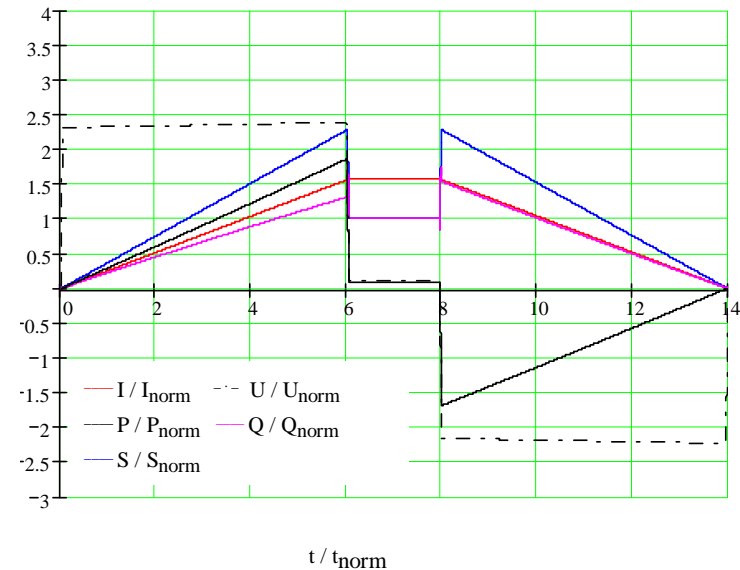
Power Requirements with Energy Recovery :

$I_{norm} = 5000 \text{ A}$ $U_{norm} = 2000 \text{ V}$ $t_{norm} = 1 \text{ s}$
 $P_{norm} = 10 \text{ MW}$ $Q_{norm} = 10 \text{ MVA}$ $S_{norm} = 10 \text{ MVA}$



SIS 300 Dipole Power Converter

$I_{norm} = 5000 \text{ A}$ $U_{norm} = 200 \text{ V}$ $t_{norm} = 1 \text{ s}$
 $P_{norm} = 2 \text{ MW}$ $Q_{norm} = 2 \text{ MVA}$ $S_{norm} = 2 \text{ MVA}$



SIS 300 Quadrupole Power Converter

Electrical Power Grid :

Power Requirements for GSI/FAIR

Substation of the public power grid

| | common power installed [kVA] | common power in operation [kVA] | pulsed power installed [kVA] | pulsed power in operation [kVA] |
|---------------------------------|------------------------------|---------------------------------|------------------------------|---------------------------------|
| Leonhardstanne | 94500 | 72000 | 94500 | 74000 |
| GSI (total) | 14000 | 12000 | 36000 | 27000 |
| FAIR (total) | 82000 | 60000 | 87600 | 68000 |
| Accelerators/Beam lines of FAIR | 48000 | 34500 | 87600 | 68000 |
| Experiments of FAIR | 14000 | 10500 | 0 | 0 |
| Cryogenics of FAIR | 10000 | 9000 | 0 | 0 |
| General supply of FAIR | 10000 | 6000 | 0 | 0 |

The „operational power“ as mentioned above is a apparent power and the transformers of the power grid have to carry it fully. This power is higher than the active power averaged over a year , as done for calculating the operating cost of the site! (Status FBTR 2006)

Electrical Power Grid :

Pulse Power of SIS 12/18, SIS 100 and SIS 300 in the High Voltage Grid

Active Power

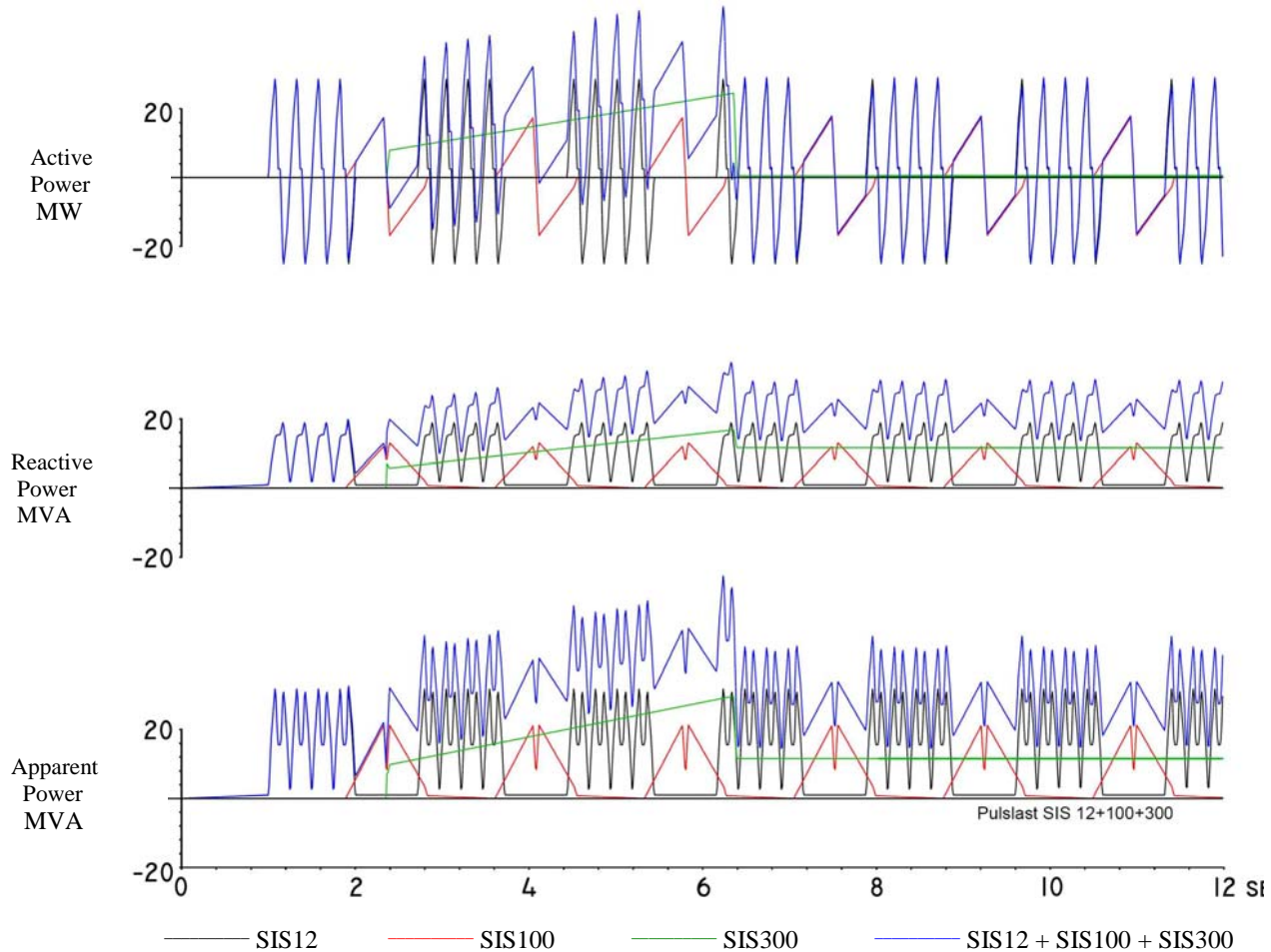


Shaft oscillations of
generators in the
grid

Reactive Power

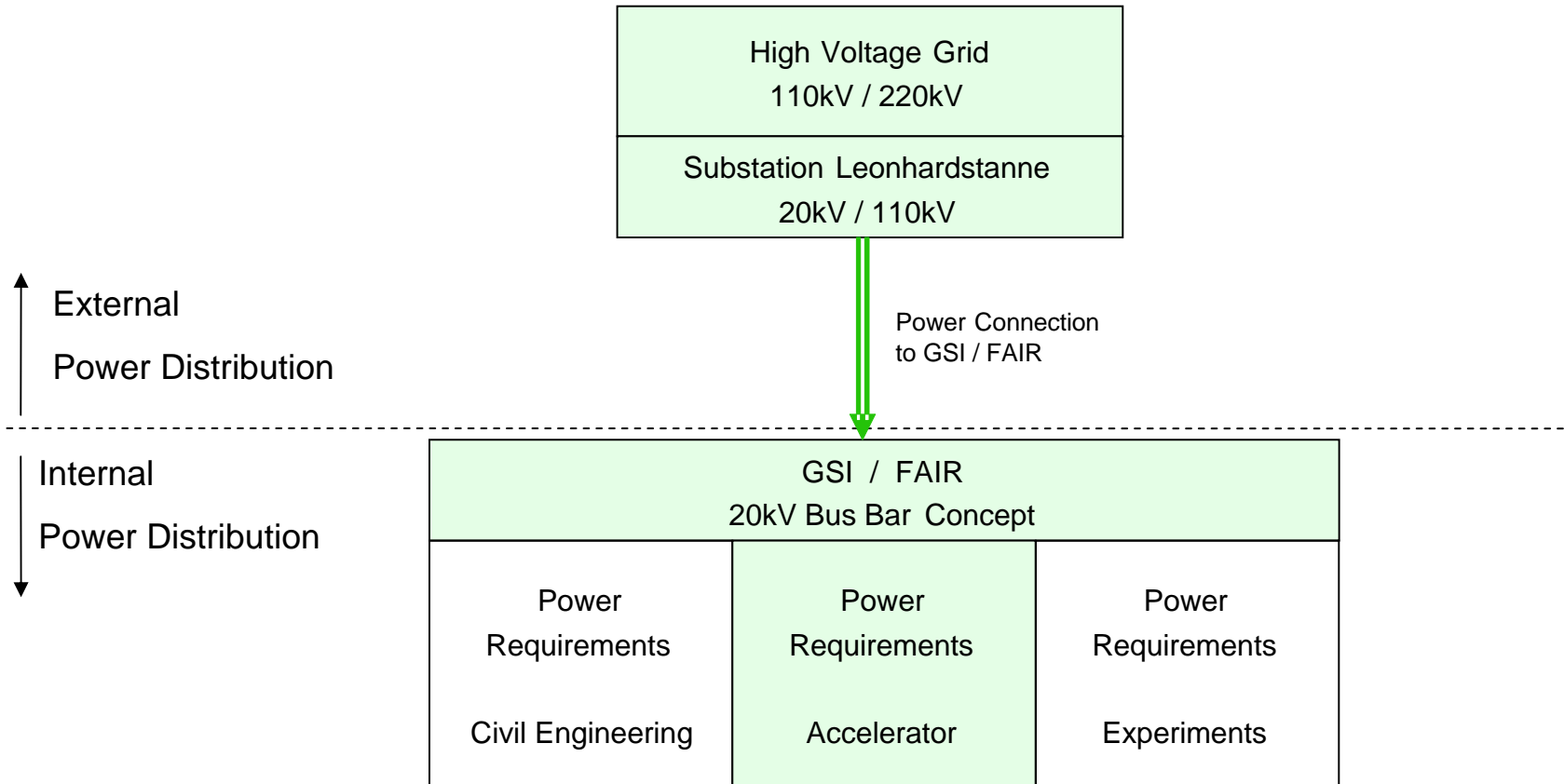


Flicker



Electrical Power Grid

Basic Topics of Electrical Power Distribution of GSI/FAIR



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Electrical Power Grid

- An Energy concept has been developed :
 - Pulsed Power is decoupled from Common Power
 - Pulsed Power of SIS18 and SIS100 are decoupled in time
 - Pulsed Power of SIS 18, SIS100 is electrically decoupled from SIS300
 - sensitive loads (experiments) have their own feeding line (common 3)
 - the cryogenic system and the general supply can be powered even in case of a major fault of their main feeding line

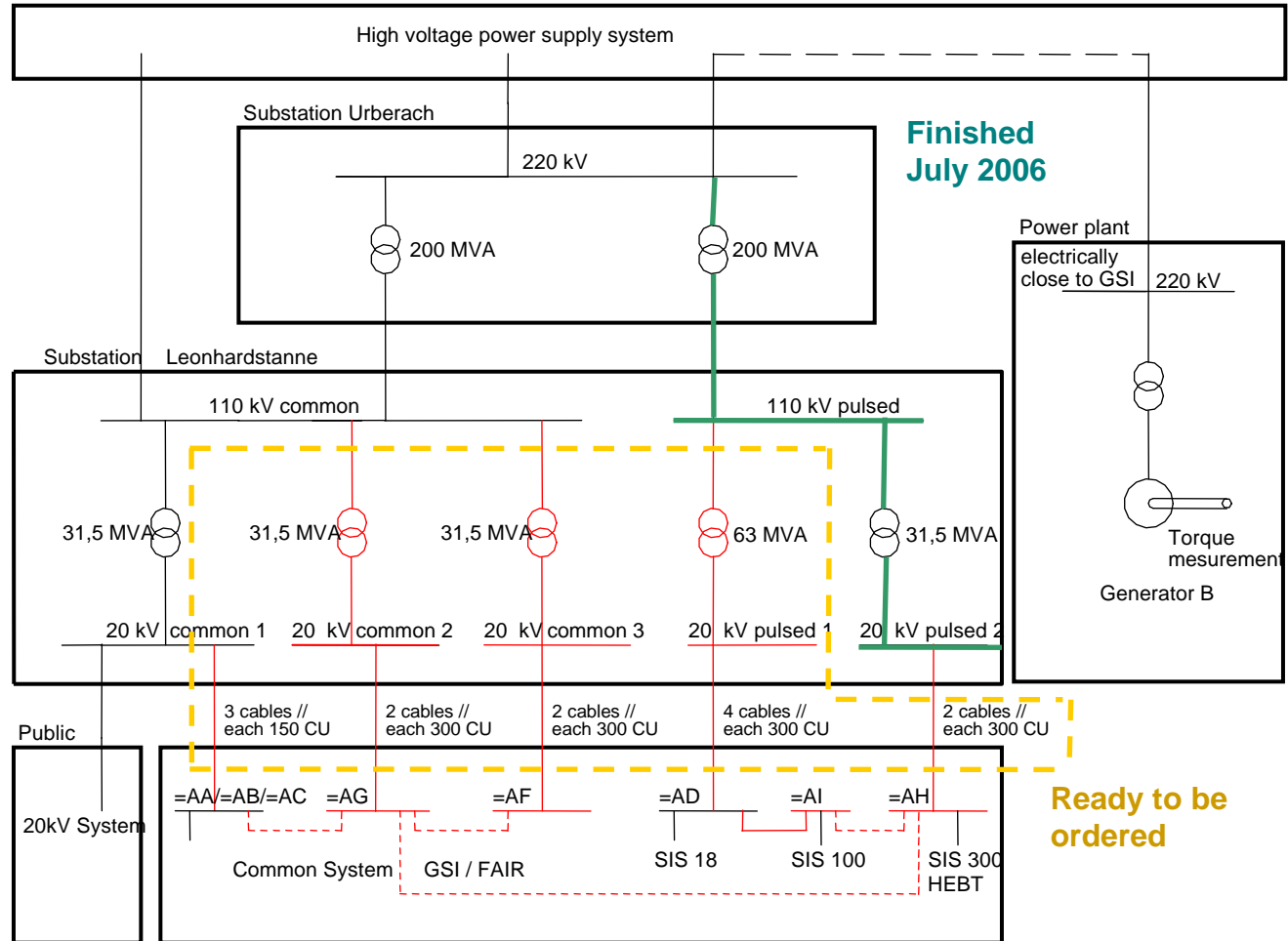
- Pulse Power Connection to the 220 kV-Grid is finished

- Rest of external Energy Concept has been specified and discussed with the local supplier (VNB Rhein- Main-Neckar) and is waiting to be orderd.

Electrical Power Grid :

External Power Distribution

GSI/FAIR Power Connection



Finished
July 2006

Ready to be
ordered



Pulse power :
1 : 63 MVA
2 : 31.5 MVA

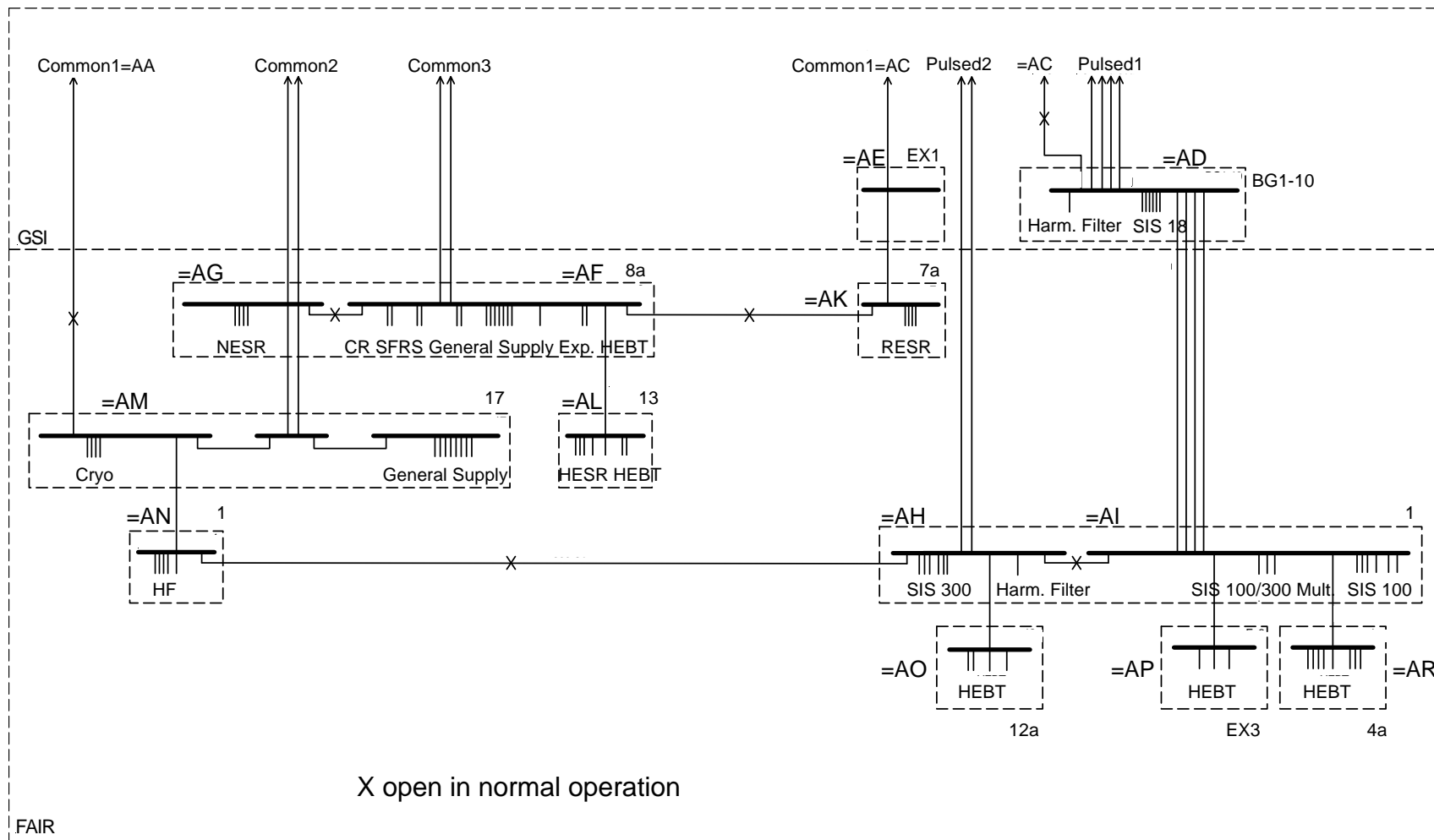
Common power
1 : 31.5 MVA
2 : 31.5 MVA
3 : 31.5 MVA

New transformers are marked red .

Electrical Power Grid :

20 kV bus bar concept

Internal Power Distribution



Upgrade of Unilac and SIS18 Power Converters :

- Finished and in operation :
 - Power Converter for Inflector magnet (SIS18): 2100A DC, 24kA/s and 111V
 - Power Converters for additional horz. correctors (SIS18): +/-60A, 650A/s, 105V induced

- Finished and going to be installed (May 2008):
 - HV Power Converter for el. Injection Septum (SIS18): 300kV, 150kV in 67ms

- In production:
 - 18 Power Converters for Alvarez Quadrupoles (UNILAC): 210A...390A, 49V...543V, tr=1s
start of operation November 2008

Upgrade of Unilac and SIS18 Power Converters :

- Waiting for being ordered :

- Upgrade of Power Converter System for Main Dipol Magnets (SIS18): 3500A, 19kA/s
(present 2300A, 19kA/s)

- Compatibility of increased short circuit capacity to existing 20kV GSI busbars has been checked

- Studies on harmonic filtering on 20kV level have been performed

- Original manufacturer confirmed the upgrade solution

4 new 12 pulse SCR power transformers are needed

4 new smoothing reactors are needed

internal power cabling must be adapted

20kV switch gear has to be modified

New harmonic filter on 20kV level is needed

Upgrade of Unilac and SIS18 Power Converters :

- Waiting for being ordered :

- Continued

Upgrade of Power Converter System for Main Dipol Magnets (SIS18): 3500A, 19kA/s
(present 2300A, 19kA/s)

- * existing SCR units shall be used
- * existing high dynamic active parallel filter units shall be used
- * existing high precision DCCT will be used
- * existing control and protection electronics shall be used

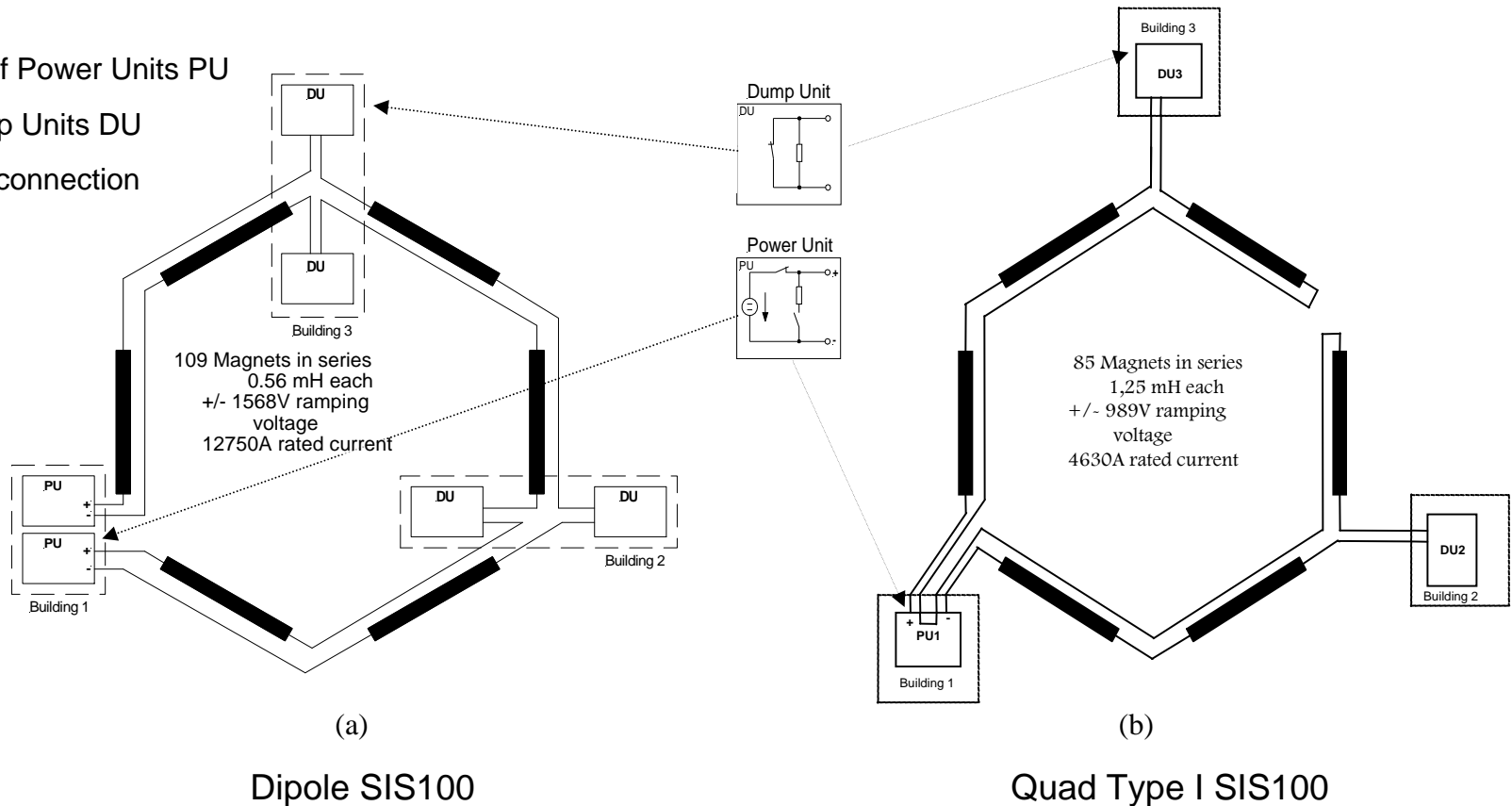
FAIR Power Converters :

- Finished and in operation :
 - Power Converter for Magnet Test Stand (SC) : 11kA, 100V
 - First generation of digital control hardware and software : approx. 150 power converters of Therapy accelerator in Heidelberg
- Finished :
 - Study on Electronic Circuit Breaker for quench protection <1ms, 6kA, 1200V
and first prototype : TU-Darmstadt
- In Production :
 - Advanced prototype of electronic circuit breaker : <1ms, 13kA, 1200V
- Converging:
 - Parameter lists and costs for all Power Converters : TDR and Costbook

FAIR Power Converters :

- Defined : Topology of Power Converters Systems

System of Power Units PU
and Dump Units DU
in series connection



FAIR Power Converters :

- Defined : Design of dedicated Power Converters

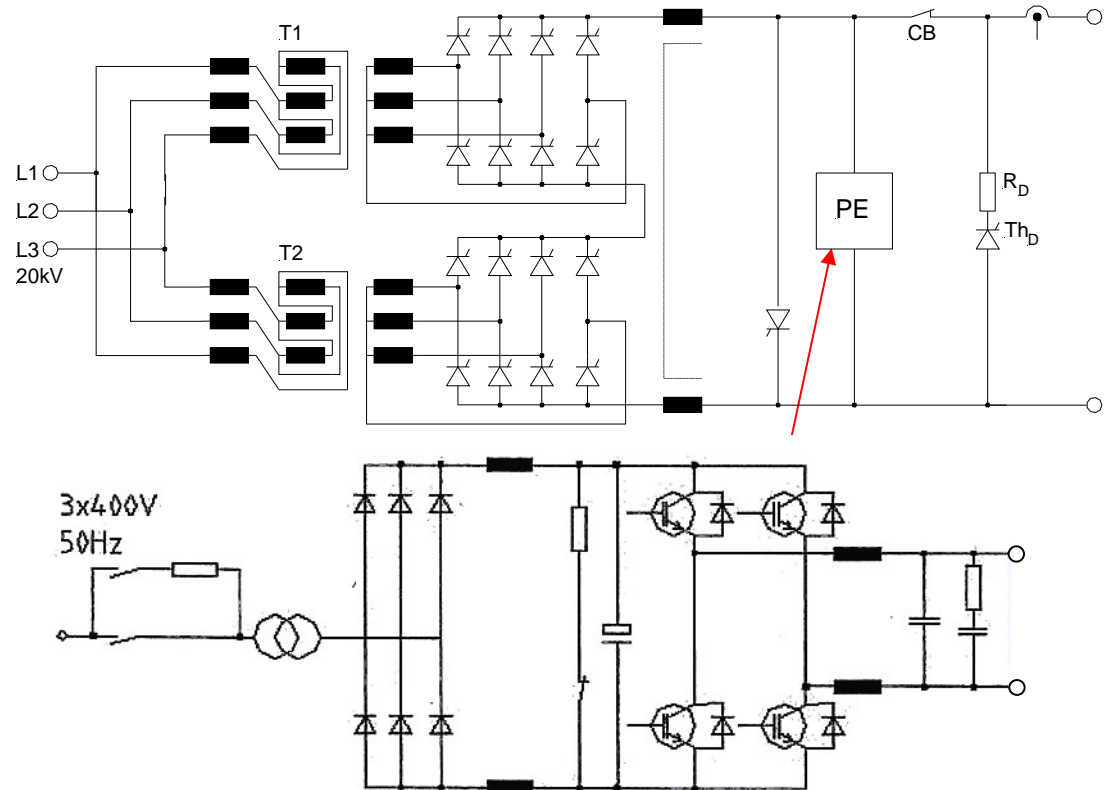
Type SCR_ramped

A power unit PU has basically 3 major components:

a twelve pulse SCR with controlled freewheeling thyristors. This component handles the large power.

an active parallel filter PE. This component takes care of the current ripple and current dynamics.

a quench protection circuit. This component absorbs the magnet energy and disconnects the magnet string from the active power part of the converter. For the SIS 100 power converters a circuit breaker with an opening time of <1ms is necessary.



FAIR Power Converters :

-Basic decision : Power Converters have to be placed in areas which are accessible even when beam is on.

- There are drafts of Specifications consisting of 3 parts:

- General Remarks : legal and financial aspects, general rules
- Common Remarks: special technical rules, general technical requirements, environmental conditions
- Technical specification: detailed technical description and parameters, interfaces



FAIR Power Converters :

Machine Overlapping Systems and possible In-Kind-Contributions

| | HEBT | SIS100 | SIS300 | CR | RESR | NESR | ER | SFRS | PBAR | HESR | P-Linac |
|--------------------------------------------------|------|--------|--------|-----|------|------|-----|------|------|------|---------|
| Embedded Control Unit | Red | Red | Red | Red | Red | Red | Red | Red | Red | Red | Red |
| High precision current measurement (DCCT) | Red | Red | Red | Red | Red | Red | Red | Red | Red | Red | Red |
| Electronic DC-Circuit Breaker | | Red | Red | | | | | | | | |
| Main Dipole Power Converter (for sc magnets) | | Red | Red | | | | | | | | |
| Main Dipole Power Converter (for nc magnets) | | | | | Blue | Blue | | | | | |
| Main Quadrupole Power Converter (for sc magnets) | | Blue | Blue | | | | | | | | |
| Steerer Power Converter (for sc magnets) | | Blue | Blue | | | | | | | | |
| Quadrupole long Power Converter | | | | | Blue | Blue | | | | | |
| Sextupole narrow Power Converter | | | | | Blue | Blue | | | | | |
| Quench Heaters | Blue | | Blue | | | | | | | | |
| Quench Detection Electronics | Blue | Blue | Blue | | | | | | | | |



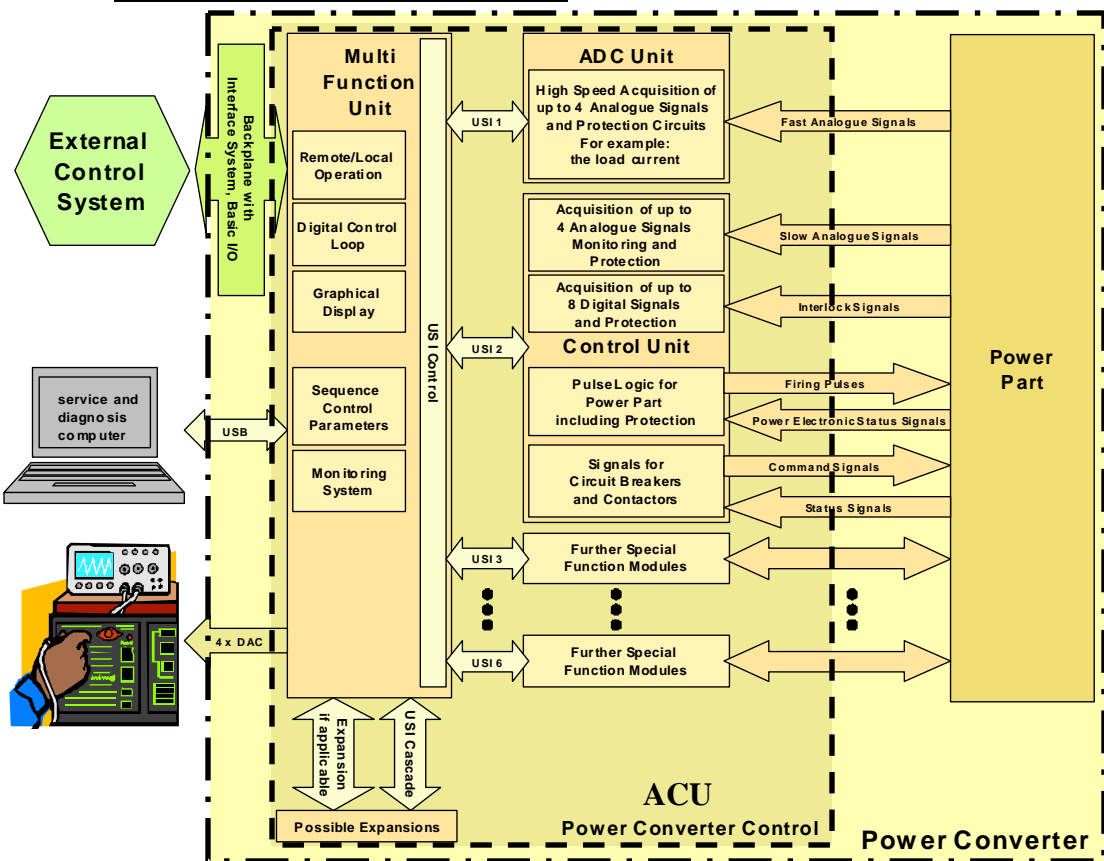
German In-Kind-Contribution



International In-Kind-Contribution

FAIR Power Converters :

- Power Converter Control:



German In-kind contribution

Adaptive Control Unit ACU

- Multifunction unit
- control unit
- [ADC unit]

The digital control algorithm is based on analogue control strategies enhanced by the possibilities of digital signal processing.

All parameters of the control algorithm can be loaded and read by the external control system.

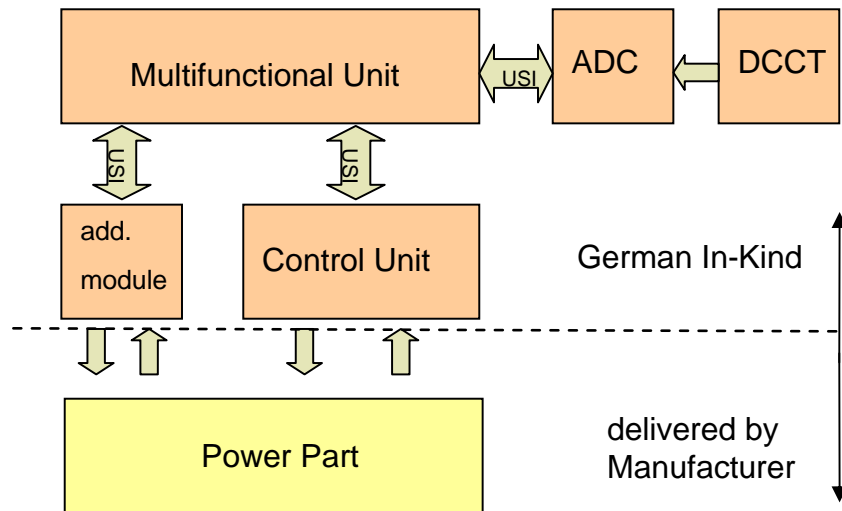
German In-kind contribution
DCCT (with digital output)

ACU is second generation of digital control hardware and will be used in Alvarez Power Converters

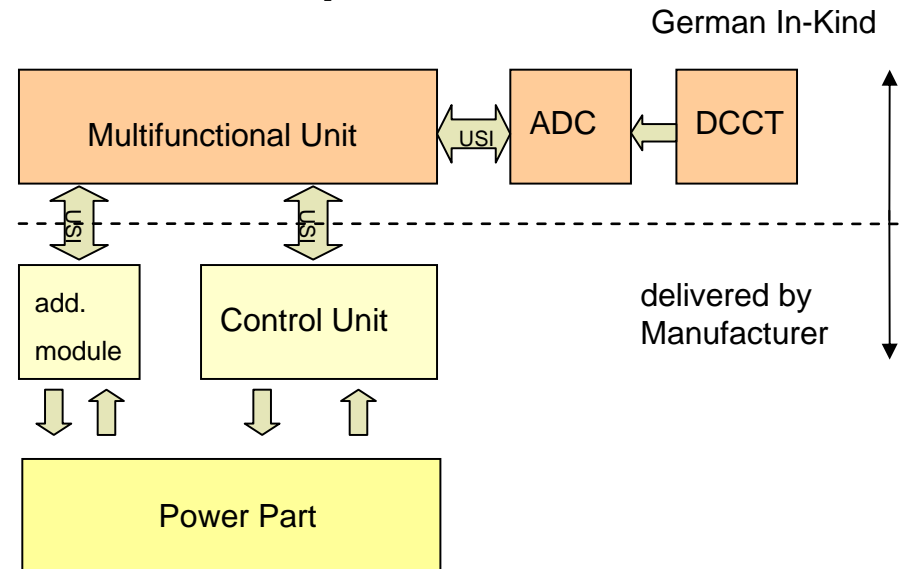
FAIR Power Converters :

Use of ACU

Example 1



Example 2

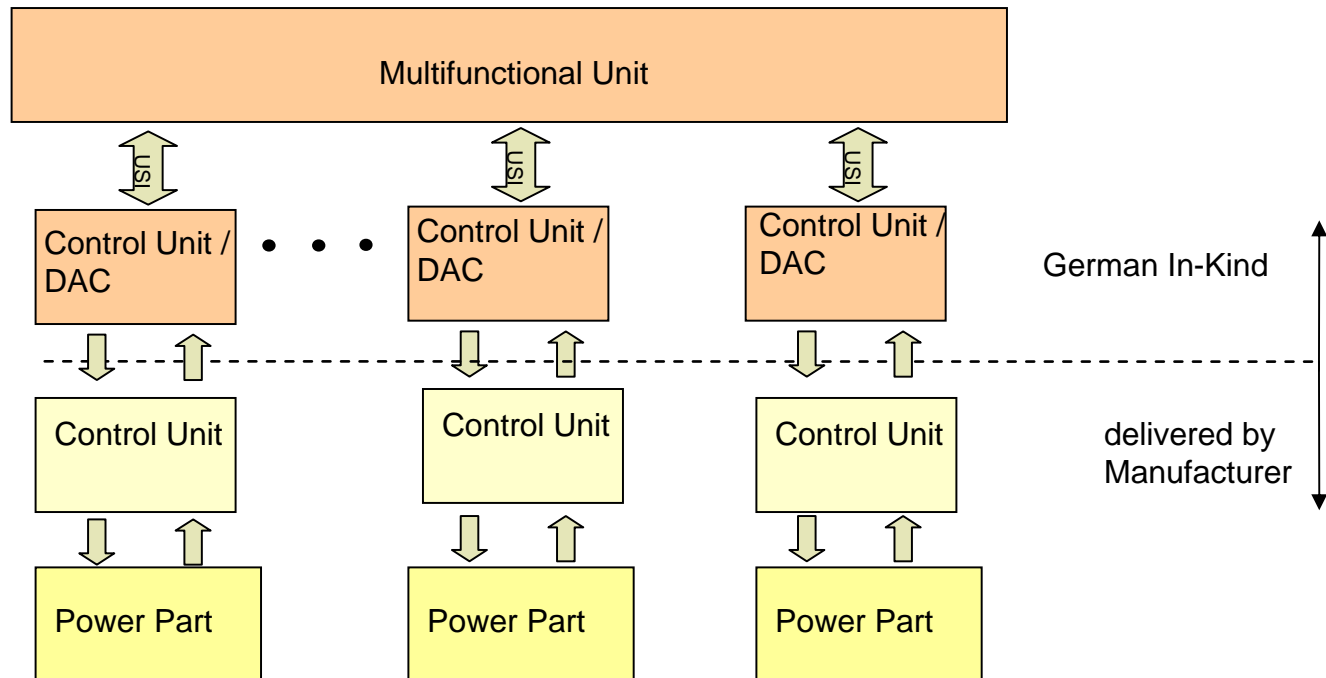


Manufacturer will be responsible for the functionality of the complete system in both cases.

In-kind components have to be used like other commercial components on the market.

FAIR Power Converters :

Use of ACU Example 3

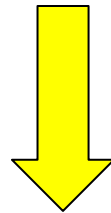


The analogue current regulation and current measurement is included in the delivery of the Manufacturer. Up to six devices can be supplied by one multifunctional unit.

FAIR Power Converters :

Status May 2008 :

- Waiting for final decision on In-Kind-Contributions
- Waiting for final decision on taking over dedicated work packages



No contracts for power converters of FAIR

Official start of project: 7th November 2007

First beam : 2013 / 2014