3.2.3 Power supplies

The booster power supply complement consists of

1	BDBF bending magnets power supply
1	QD quadrupole magnets power supply
1	QE quadrupole magnets power supply
1	QF quadrupole magnets power supply
1	SD sextupole magnets power supply
1	SF sextupole magnets power supply
54	CV vertical corrector magnet power supplies
54	CH horizontal corrector magnet power supplies
1	BFC corrector magnet power supply

a) BOMA-BD/BF Bending Magnet Power Supply (BOPS-B)

All the combined function dipoles are powered in series, 48 BOMA-BDs and 45 BOMA-BFs.

To power the magnets in a booster synchrotrons it is quite popular to use a so called resonant "White circuit", where the electromagnetic energy oscillates between an inductive storage (magnets+chokes) and a capacitor bank. This scheme is very useful for high repetition rates and high Q value of the resonating circuit.

If all magnets of one type are powered in series the induced voltage can reach a few kV resulting in the usual precautions necessary for a high voltage installation.

In our case the White circuit becomes less attractive, since on one hand the energy stored in the magnets is low (less than 30 kJ) and on the other hand a repetition rate of e.g. 3Hz is sufficient to fill the storage ring in less than 2 minutes.

As an alternative we use current/voltage regulated power supplies, offering the following features:

- flexible choice of the repetition rate up to 3 Hz
- programmable ramping profile for the current between a triangle and a (1-cos3Hz) function (the choice of low dB/dt at injection to reduce sextupole field induced by eddy current in vacuum chamber).
  $\rightarrow$ smooth variation of B(t) to avoid transients due to delay line mode effects
- maximum total voltage (DC+AC) $\cong$ 1kV (all dipoles in series)
- possibility of a low duty cycle mode for top-up operation; long dead time between pulses (seconds)
- possibility to run booster in a storage ring mode up to 1.6 GeV

SPECIFICATIONS

Magnet Load	see magnet specifications	
Cabling	700 m, 2x300 mm2	R= 22 mΩ
Power supply units	1	
Current (nominal) I_N	950 A	
Current (minimal)	9.5 A	1 %
Current gradient (max)	10 kA/s	
Voltage	1000 V	
Operating quadrants	(+U +I) and (-U +I)	2 Q
- 3 dB control bandwidth	1 kHz	
Stability (8 h - 10 s) referred to I_N	40 ppm	
Stability (10 s - 100 ms) referred to I_N	20 ppm	
Stability (0 - 100 ms) referred to I_N	10 ppm	
Accuracy, absolute, referred to 4% I_N	1000 ppm	at 3 Hz I_N
Reproducibility long term referred to I_N	100 ppm	
Resolution of reference value	16 bit	18 bit desirable
Resolution of measured value	14 bit	

SOLUTION

The proposed power supply consists of two identical power modules connected in series (full current = 950A half voltage = 500V , each). See also reference (2). Figure f323_a shows the associated block diagram.

POWER MODULE

The circuit of one module contains a transformer and a 12 pulse rectifier set. The subsequent DC-chopper charges the storage capacitor bank. The current is controlled to ensure a constant current flow out of the rectifier, hence a constant power drawn from the supply line. The capacitor bank is made of 80 electrolytic capacitors and acts as an energy buffer.

A two-quadrant switchmode circuit controls the magnet voltage necessary for the ohmic and inductive part required by the current waveform.

The two switches (IGBT) of this circuit are operated at 10kHz with pulse width modulation and 180 degrees phase shift. The output voltage of this switchmode circuit passes a double section filter which reduces the output ripple voltage (20kHz) to 1V for each module.

The second module`s phase is shifted by 90 degrees. Therefore the total voltage ripple of the two modules connected in series is mainly 40kHz and reduced to a value smaller than 0.1V

Figure f323_b shows the example of a sinusoidal variation of the magnet current at

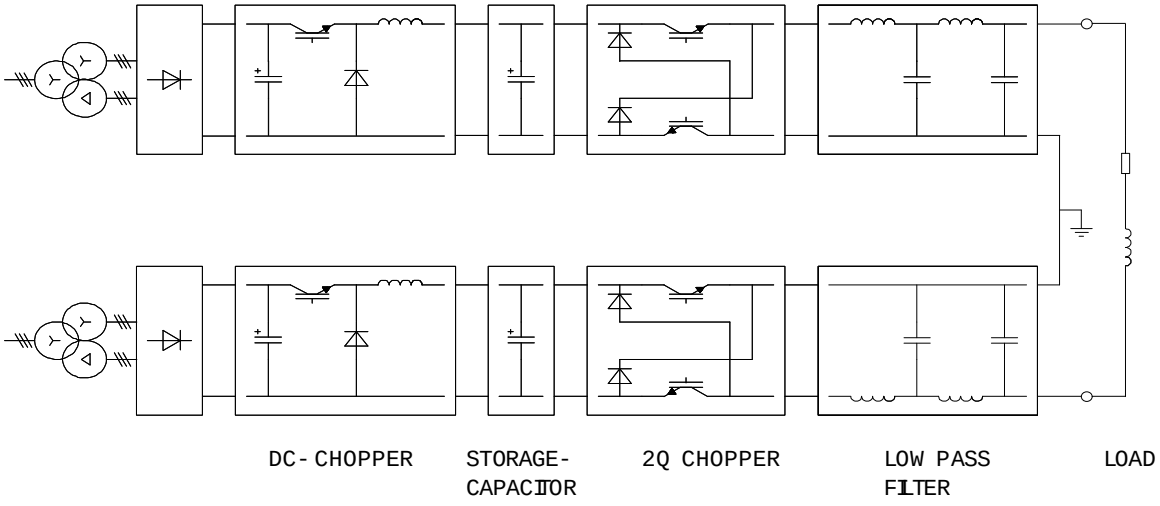

Fig. f323_a: Block diagram of the switch mode bending magnet BOPS-B power supply

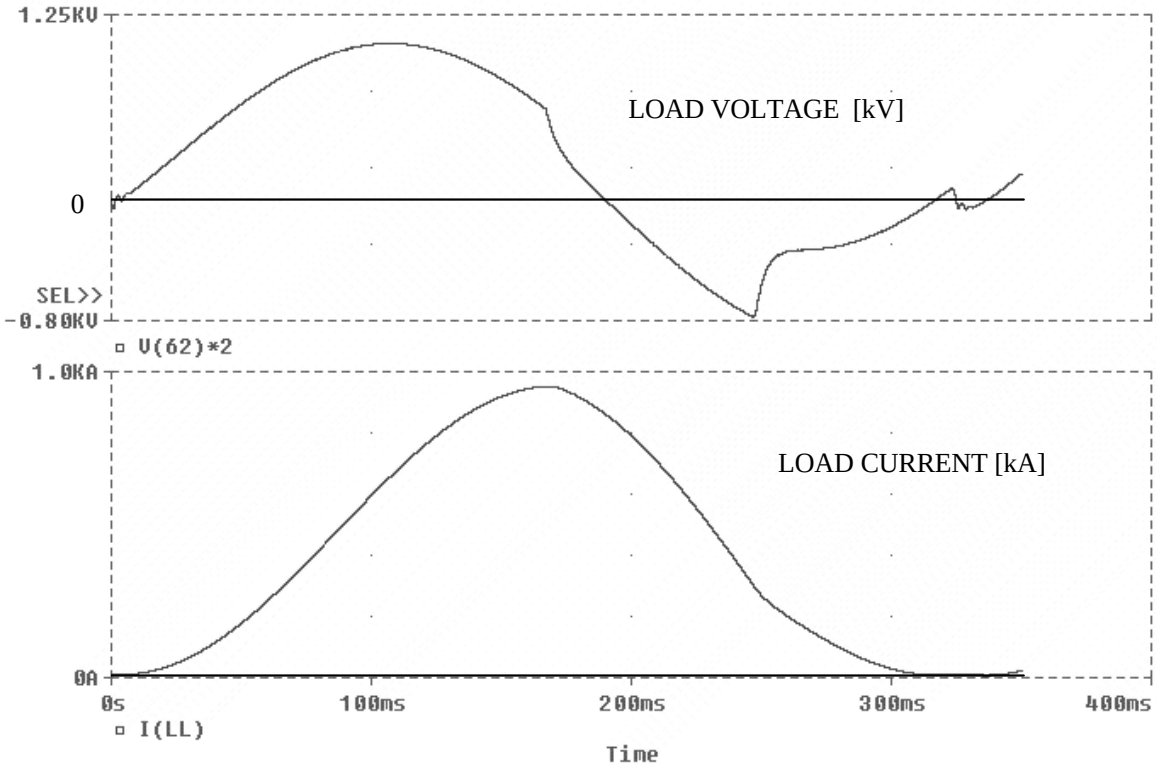

Fig. f323_b: Example of a sinusoidal variation of the magnet current in the dipoles BOMA-BD and BOMA-BF. Injection occurs at about 5% of the maximum field. The maximum total voltage (DC+AC) over the 3Hz cycle is about 1kV.

References:

(1) A novel low emittance lattice for high brilliance electron beams
W.D. Klotz, G. Mülhaupt, Another Lattice Model for High Brightness Synchrotron Radiation Sources ESRF-LAT-88-07, 1988

(2) SLS Boosterspeisung BD/BF,
G.Irminger, M.Horvat, TM 81-97-01, 6.März 1997, in German.

b) BOMA-QE Quadrupole Magnet Power Supply (BOPS-QE)

All QE-magnets are connected in series. A switch mode power supply will be used to feed the QE- family of 6 magnets.

The detailed design has not yet been started.

SPECIFICATIONS

Magnet Load	see magnet specifications	
Cabling	700 m (50 mm2)	R= 260 mΩ
Power supply units	1	
Current (nominal) I_N	40 A	
Current (minimal)	0 A	
Current gradient (max)	400 A/s	U_L= 7.2 V
Voltage	27 V	R_L= 0.25 + 0.26 Ω
Operating quadrants	4 Quadrants	
- 3 dB Control bandwidth	3 kHz	
Stability (8 h - 10 s) referred to I_N	1000 ppm	
Stability (10 s - 100 ms) referred to I_N	400 ppm	
Stability (0 - 100 ms) referred to I_N	200 ppm	
Accuracy, absolute, referred to I_N	1000 ppm	
Reproducibility long term	100 ppm	
Resolution reference value	16 bit	
Resolution measured value	14 bit	

c) BOMA-QD Quadrupole Magnet Power Supply (BOPS-QD)

All QD-magnets are connected in series. A switch mode power supply will be used to feed the QD- family of 6 magnets.

The detailed design has not yet been started.

SPECIFICATIONS

Magnet Load	see magnet specifications	I_{DC}= 62% Imax
Cabling	700 m (95 mm2)	R= 150 mΩ
Power supply units	1	
Current (nominal) I_N	160 A	
Current (minimal)	1 A	
Current gradient (max)	1600 A/s	U_L= 29 V
Voltage	93 V	R_L= 0.25 +0.15 Ω
Operating quadrants	(+U +I) and (-U +I)	2 Q
- 3 dB Control bandwidth	3 kHz	
Stability (8 h - 10 s) referred to I_N	200 ppm	
Stability (10 s - 100 ms) referred to I_N	200 ppm	
Stability (0 - 100 ms) referred to I_N	100 ppm	
Accuracy, absolute, referred to I_N	200 ppm	
Reproducibility long term	100 ppm	
Resolution reference value	16 bit	
Resolution measured value	14 bit	

d) BOMA-QF Quadrupole Magnet Power Supply (BOPS-QF)

All QF-magnets are connected in series. A switch mode power supply will be used to feed the QF- family of 12 magnets.

The detailed design has not yet been started.

SPECIFICATIONS

Magnet Load	see magnet specifications	I_{DC}= 62% Imax
Cabling	700 m (95 mm2)	R= 150 mΩ
Power supply units	1	
Current (nominal) I_N	160 A	
Current (minimal)	1 A	
Current gradient (max)	1600 A/s	U_L= 58 V
Voltage	160 V	R_L= 0.5 + 0.15 Ω
Operating quadrants	(+U +I) and (-U +I)	2 Q
- 3 dB Control bandwidth	3 kHz	
Stability (8 h - 10 s) referred to I_N	200 ppm	
Stability (10 s - 100 ms) referred to I_N	200 ppm	
Stability (0 - 100 ms) referred to I_N	100 ppm	
Accuracy, absolute, referred to I_N	200 ppm	
Reproducibility long term	100 ppm	
Resolution reference value	16 bit	
Resolution measured value	14 bit	

e) BOMA-SD Sextupole Magnet Power Supply (BOPS-SD)

All SD-magnets are connected in series. A switch mode power supply will be used to feed the SD- family of 12 magnets.

The detailed design has not yet been started.

SPECIFICATIONS

Magnet Load	see magnet specifications	
Cabling	700 m (4 mm2)	R= 3.5 Ω
Power supply units	1	
Current (nominal) I_N	10 A	3 Hz with harmonics
Current (minimal)	0 A	
Current gradient (max)	150 A/s	U_L= 30 V
Voltage	100 V	R_L= 7.8+3.5+ε ≈ 12 Ω
Operating quadrants	4 Q	
- 3 dB control bandwidth	1 kHz	
Stability (8 h - 10 s) referred to I_N	500 ppm	
Stability (10 s - 100 ms) referred to I_N	500 ppm	
Stability (0 - 100 ms) referred to I_N	500 ppm	
Accuracy, absolute, referred to I_N	500 ppm	
Reproducibility long term	500 ppm	
Resolution reference value	16 bit	
Resolution measured value	14 bit	

f) BOMA-SF Sextupole Magnet Power Supply (BOPS-SF)

All SF-magnets are connected in series. A switch mode power supply will be used to feed the SF- family of 6 magnets.

The detailed design has not yet been started.

SPECIFICATIONS

Magnet Load	see magnet specifications	
Cabling	700 m (4 mm2)	R= 3.5 Ω
Power supply units	1	
Current (nominal) I_N	10 A	3 Hz with harmonics
Current (minimal)	0 A	
Current gradient (max)	300 A/s	U_L= 30 V
Voltage	100 V	R_L= 3.9+3.5+ε ≈ 8 Ω
Operating quadrants	4 Q	
- 3 dB control bandwidth	1 kHz	
Stability (8 h - 10 s) referred to I_N	500 ppm	
Stability (10 s - 100 ms) referred to I_N	500 ppm	
Stability (0 - 100 ms) referred to I_N	500 ppm	
Accuracy, absolute, referred to I_N	500 ppm	
Reproducibility long term	500 ppm	
Resolution reference value	16 bit	
Resolution measured value	14 bit	

g) BOMA-CH / CV Corrector Magnet Power Supplies (BOPS-CH and BOPS-CV)

All corrector -magnets are individually powered, 54 BOMA-CH and 54 BOMA-CV.

The detailed design has not yet been started.

SPECIFICATIONS

Magnet Load	see magnet specifications	
Cabling	200 m (1.5 mm2)	R= 2.6 Ω worst case
Power supply units	108	54 BPS-CH and 54 BPS-CV
Current (nominal) I_N	2.7 A	DC with 3 Hz and harmonics
Current (minimal)	0 A	
Current gradient (max)	100 A/s	U_L= 7 V
Voltage	20 V	R_L= 4 Ω
Operating quadrants	4 Q	
- 3 dB control bandwidth	1 kHz	
Stability (8 h - 10 s) referred to I_N	1000 ppm	
Stability (10 s - 100 ms) referred to I_N	1000 ppm	
Stability (0 - 100 ms) referred to I_N	1000 ppm	
Accuracy, absolute, referred to I_N	1000 ppm	
Reproducibility long term	1000 ppm	
Resolution reference value	12 bit	
Resolution measured value	12 bit	

h) BOMA-BFC Corrector Magnet Power Supplies (BOPS-BFC)

An additional corrector winding is mounted on each of the 45 BOMA-BF booster bending magnets (BOMA-BFC). All corrector magnets are wired in series and powered by its BOPS-BFC power supply.

The detailed design has not yet been started.

SPECIFICATIONS

Magnet Load	see magnet specifications	
Cabling	700 m (1.5 mm2)	R= 9 Ω
Power supply units	1	
Current (nominal) I_N	2 A	
Current (minimal)	0 A	
Current gradient (max)	0 A/s	U_L= 7 V
Voltage	50 V	R_L= 5+9 ˜ 15 Ω
Operating quadrants	4 Q	
- 3 dB control bandwidth	300 Hz	
Stability (8 h - 10 s) referred to I_N	10000 ppm (1 %)	
Stability (10 s - 100 ms) referred to I_N	10000 ppm (1 %)	
Stability (0 - 100 ms) referred to I_N	10000 ppm (1 %)	
Accuracy, absolute, referred to I_N	10000 ppm (1 %)	
Reproducibility long term	1000 ppm	
Resolution reference value	12 bit	
Resolution measured value	12 bit	