BNL-99520-2013-TECH

C-A/AP/373;BNL-99520-2013-IR

Energy Recovery Linac: Power Supplies

R. Lambiase

January 2010

Collider Accelerator Department

Brookhaven National Laboratory

U.S. Department of Energy

USDOE Office of Science (SC)

BNL-90927-2010-IR

C-A/AP/#373
January 2010

R&D ERL: Power Supplies

R. Lambiase

Collider-Accelerator Department
Brookhaven National Laboratory
Upton, NY 11973

R&D ERL – Power Supplies
R. Lambiase
February 17, 2010

A magnet power supply system has been developed to meet the field requirements of the ERL in a compact and cost effective fashion.

Design Considerations

The magnet assemblies used in the ERL consist of one or more windings on a common core. Each of the windings represents a separate magnet load for the power supply. As the ERL is operated in a DC fashion, interaction between the windings is not a concern.

Appendix A lists all the magnet assemblies by sector. Each coil is listed by name and model. The model corresponds to a set of electrical and magnet parameters as established by the magnet subsystem.

Some of the coils are connected in series. The connection scheme, plus cabling provides the electrical load characteristics. The load information, plus the operating current, and the stability define the power supply requirements.

Power Supply Listing

All of the magnet power supply requirements for ERL can be satisfied by five different models. The capsule specifications and quantities are shown in Table 1 below.

Model	Voltage, Volts	Current, Amps	Precision, ppm	Quantity
UD320A35V, IE Power	35	320	100	1
Shim Amplifier 892, Danfysik	15	10	100	34
BOP 50-20GL, Kepco	50	20	100	5
MCOR12 / 2A, BiRa	25	2	1000	32
MCOR12 / 6A, BiRa	25	6	1000	6

With the exception of the UD320A35V unit, all models are bipolar, even though not all loads require bipolar operation. But, by using standard off-the-shelf units, development costs were minimized.

Appendix B lists each power supply, by model, with its magnet load. The total AC power requirements for all of these units are estimated at 13.2 KVA of 480 VAC, 3 phase and 25.3 KVA of 208 VAC, 3 phase. Appendix C breaks down this estimate by power supply model.

UD320A35V, IE Power

Ratings: 320A, 35V, 100ppm
Qty: 1

This supply is used to power the six main dipoles in series. It can be seen as the cabinet on the left in Figure 1.

This supply is a thyristor controlled supply using the same design, but slightly different rating, as the 77 medium range power supplies built for the SNS at ORNL.

This supply is controlled by a standard BNL Power Supply Interface (PSI).

BOP 50-20GL, Kepco

Ratings: 50V, 20A, 100ppm
Qty: 5

This supply is used where higher voltage is needed, typically where there is more than one coil in series as a load. All five units can be seen mounted in the cabinet on the right in Figure 1.

Figure 1. IE Power & Kepco Supplies

These switch mode supplies are a high precision version of the standard Kepco high power BOP. The extra precision is obtained by closing the current loop around a zero flux current sensor (ZFCT) and adding additional output filtering to reduce the output ripple to a level consistent with the higher precision.

Control of these supplies will be by RS-232.

Shim Amplifier 892, Danfysik

Ratings: 10A, 15V, 100ppm
Qty: 34

All 34 supplies, plus two spares, are shown in Figure 2. Each crate consists of a bulk power supply and six regulators. Each regulator has a front end switching pre-regulator followed by a linear H bridge. The high stability is maintained by an on-board ZFCT.

These power supplies are scaled down versions of the 20A, 70V low field correctors designed for the ORNL SNS. By reducing the power, these were able to be packaged in a compact configuration, and used to power shim windings on MRI machines. It's also very useful for us to have this many high precision power supplies in a small volume.

Each channel can be individually manually controlled by the controller seen at the top of the left cabinet. It has the capability to address and control up to 256 regulators.

In operation, these supplies will be controlled by a RS-485 line.

Figure 2. Danfysik Power Supplies

MCOR12 / 2A, BiRa

Rating: 2A, 25V, 1000ppm
Qty: 32

MCOR12 / 6A, BiRa

Rating: 6A, 25V, 1000ppm
Qty: 6

These magnet power supplies are shown in Figure 3. The 32 regulators rated at 2A each in two crates in the left cabinet, and the six regulators rated at 6A each are in the crate in the right cabinet.

This magnet corrector power supply system was designed at SLAC, and built to their specification by BiRa.

Each crate contains one analog interface board and up to 16 MCOR12 regulator cards that can be configured as 2A, 6A, or 12A by means of a programming daughter board.

These regulators are powered by a commercial unipolar power supply. In our application, these are Genesys 30V, 50A units.

Figure 3. BiRa Power Supplies

Completing the system is a 2U blower assembly which goes between the bulk power supply and the crate. It draws air from the front panel through a filter and directs it up between the cards.

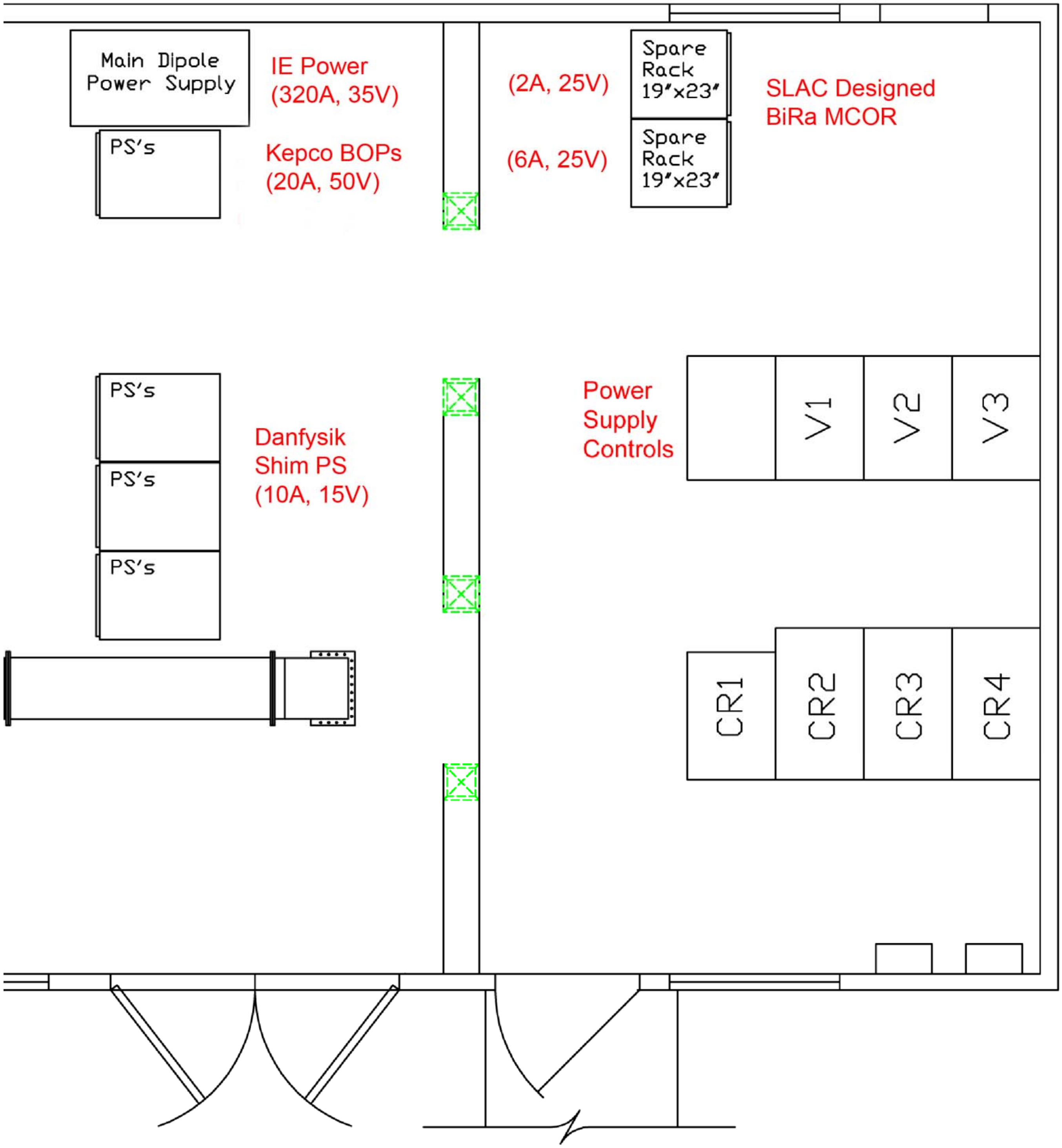
Each regulator accepts (via the interface card) one analog current set point, and returns one analog current read back. These signals will come from VME DACs and ADCs in the control crate. In addition, each crate has a group interlock, and group status.

An RS-232 digital interface, which includes the ADC and DAC functions is under development at SLAC, but is not completed at this time.

Rack Layout

The magnet power supplies are all located in a room above the transmitter water room. The arrangement of racks is shown in Figure 4.

Figure 4. Power Supply Rack Layout



Main Dipole Power Supply
IE Power
(320A, 35V)
PS's
Kepco BOPs
(20A, 50V)
(2A, 25V)
(6A, 25V)
Spare Rack 19"x23"
Spare Rack 19"x23"
SLAC Designed
BiRa MCOR
PS's
PS's
PS's
Danfysik
Shim PS
(10A, 15V)
Power
Supply
Controls
V1
V2
V3
CR1
CR2
CR3
CR4

Construction Status

All of the magnet power supplies have been delivered, and are nearly fully installed mechanically. Work will continue with installing cables for AC power to the equipment, DC cables from the equipment to the magnets, and control cables from the control system to the power supplies.

This work should be completed by June 2010.

Commissioning Plans

All of the power supplies have been tested at the factory, and there are no technical complexities to commissioning these supplies. The control interface design will be tested prior to the actual magnet loads being connected and the final system testing will proceed as the magnet loads are connected.

Appendix A

Magnet Configuration by Sector

Sector: 1

Magnet Position 1 - 1:

Assembly	ELS1.1	Assembly Model:	10S10HTS	High Temp SC solenoid
Coil Name:	ELS1.1	Coil Model:	10S10HTS	PS: Shim Amplifier 892

Sector: 2

Magnet Position 2 - 1:

Assembly	ELS2.1	Assembly Model:	11S10	Diagnostic solenoid
Coil Name:	ELS2.1	Coil Model:	11S10	PS: Shim Amplifier 892
Assembly	ELC2.1	Assembly Model:	5D10	Air coils around 6-way cross
Coil Name:	ELC2.1CH	Coil Model:	5DH10	PS: MCOR12 / 2A
Coil Name:	ELC2.1CV	Coil Model:	5DV10	PS: MCOR12 / 2A

Sector: 3

Magnet Position 3 - 1:

Assembly	ELD3.1	Assembly Model:	7C15	15 degree combined function
Coil Name:	ELD3.1	Coil Model:	7CD15	PS: Shim Amplifier 892
Coil Name:	ELD3.1CH	Coil Model:	7CDHT15	PS: MCOR12 / 2A
Coil Name:	ELD3.1Q	Coil Model:	7CQ15	PS: MCOR12 / 2A
Coil Name:	ELD3.1X	Coil Model:	7CX15	PS: MCOR12 / 2A

Magnet Position 3 - 2:

Assembly	ELD3.2	Assembly Model:	7C30	30 degree combined function
Coil Name:	ELD3.2	Coil Model:	7CD30	PS: Shim Amplifier 892
Coil Name:	ELD3.2CH	Coil Model:	7CDHT30	PS: MCOR12 / 2A
Coil Name:	ELD3.2Q	Coil Model:	7CQ30	PS: MCOR12 / 2A
Coil Name:	ELD3.2X	Coil Model:	7CX30	PS: MCOR12 / 2A

Magnet Position 3 - 3:

Assembly	ELD3.3	Assembly Model:	7C15	15 degree combined function
Coil Name:	ELD3.3	Coil Model:	7CD15	PS: Shim Amplifier 892
Coil Name:	ELD3.3CH	Coil Model:	7CDHT15	PS: MCOR12 / 2A
Coil Name:	ELD3.3Q	Coil Model:	7CQ15	PS: MCOR12 / 2A
Coil Name:	ELD3.3X	Coil Model:	7CX15	PS: MCOR12 / 2A

Magnet Position 3 - 4:

Assembly	ELD3.4	Assembly Model:	7C30	30 degree combined function
Coil Name:	ELD3.4	Coil Model:	7CD30	PS: Shim Amplifier 892
Coil Name:	ELD3.4CH	Coil Model:	7CDHT30	PS: MCOR12 / 2A
Coil Name:	ELD3.4Q	Coil Model:	7CQ30	PS: MCOR12 / 2A
Coil Name:	ELD3.4X	Coil Model:	7CX30	PS: MCOR12 / 2A

Sector: 4

Magnet Position 4 - 1:

Assembly	ELS4.1	Assembly Model:	11S10	Injection line solenoid
Coil Name:	ELS4.1	Coil Model:	11S10	PS: BOP 50-20GL

Magnet Position 4 - 2:

Assembly	ELS4.2	Assembly Model:	11S10	Injection line solenoid
Coil Name:	ELS4.2	Coil Model:	11S10	PS: BOP 50-20GL

Magnet Position 4 - 3:

Assembly	ELS4.3	Assembly Model:	11S10	Extraction line solenoid
Coil Name:	ELS4.3	Coil Model:	11S10	PS: BOP 50-20GL

Magnet Position 4 - 4:

Assembly	ELS4.4	Assembly Model:	11S10	Extraction line solenoid
Coil Name:	ELS4.4	Coil Model:	11S10	PS: BOP 50-20GL

Sector: 5

Magnet Position 5 - 1:

Assembly	ELS5.1	Assembly Model:	11S10	Solenoid after the chicane
Coil Name:	ELS5.1	Coil Model:	11S10	PS: BOP 50-20GL
Assembly	ELD5.1	Assembly Model:	6D20	1st Extraction dipole
Coil Name:	ELD5.1	Coil Model:	6D20	PS: BOP 50-20GL
Coil Name:	ELD5.1CH	Coil Model:	6DT20	PS: MCOR12 / 2A

Magnet Position 5 - 2:

Assembly	ELS5.2	Assembly Model:	11S10	Solenoid after the chicane
Coil Name:	ELS5.2	Coil Model:	11S10	PS: BOP 50-20GL
Assembly	ELD5.2	Assembly Model:	6D40	Compensating chicane
Coil Name:	ELD5.2	Coil Model:	6D40	PS: BOP 50-20GL
Coil Name:	ELD5.2CH	Coil Model:	6DT40	PS: MCOR12 / 2A

Magnet Position 5 - 3:

Assembly	ELD5.3	Assembly Model:	6D20	Compensating chicane
Coil Name:	ELD5.3	Coil Model:	6D20	PS: BOP 50-20GL
Coil Name:	ELD5.3CH	Coil Model:	6DT20	PS: MCOR12 / 2A

Sector: 6

Magnet Position 6 - 1:

Assembly	ELD6.1	Assembly Model:	3D60	60 degree dipole, 20 cm radius
Coil Name:	ELD6.1	Coil Model:	3D60	PS: UD320A35V
Coil Name:	ELD6.1CH	Coil Model:	3DT60	PS: MCOR12 / 6A
Assembly	ELQ6.1	Assembly Model:	6Q12	Regular quadrupole
Coil Name:	ELQ6.1	Coil Model:	6Q12	PS: Shim Amplifier 892

Magnet Position 6 - 2:

Assembly	ELQ6.2	Assembly Model:	6Q12	Regular quadrupole
Coil Name:	ELQ6.2	Coil Model:	6Q12	PS: Shim Amplifier 892
Coil Name:	ELQ6.2CV	Coil Model:	6QTV12	PS: MCOR12 / 2A

Magnet Position 6 - 3:

Assembly	ELQ6.3	Assembly Model:	6Q12	Regular quadrupole
Coil Name:	ELQ6.3	Coil Model:	6Q12	PS: Shim Amplifier 892

Sector: 7

Magnet Position 7 - 1:

Assembly	ELD7.1	Assembly Model:	3D60	60 degree dipole, 20 cm radius
Coil Name:	ELD7.1	Coil Model:	3D60	PS: UD320A35V
Coil Name:	ELD7.1CH	Coil Model:	3DT60	PS: MCOR12 / 6A
Assembly	ELQ7.1	Assembly Model:	6Q12	Regular quadrupole
Coil Name:	ELQ7.1	Coil Model:	6Q12	PS: Shim Amplifier 892
Coil Name:	ELQ7.1CH	Coil Model:	6QTH12	PS: MCOR12 / 2A

Magnet Position 7 - 2:

Assembly	ELQ7.2	Assembly Model:	6Q12	Regular quadrupole
Coil Name:	ELQ7.2	Coil Model:	6Q12	PS: Shim Amplifier 892
Coil Name:	ELQ7.2CV	Coil Model:	6QTV12	PS: MCOR12 / 2A

Magnet Position 7 - 3:

Assembly	ELQ7.3	Assembly Model:	6Q12	Regular quadrupole
Coil Name:	ELQ7.3	Coil Model:	6Q12	PS: Shim Amplifier 892

Sector: 8

Magnet Position 8 - 1:

Assembly	ELD8.1	Assembly Model:	3D60	60 degree dipole, 20 cm radius
Coil Name:	ELD8.1	Coil Model:	3D60	PS: UD320A35V
Coil Name:	ELD8.1CH	Coil Model:	3DT60	PS: MCOR12 / 6A
Assembly	ELQ8.1	Assembly Model:	6Q12	Regular quadrupole
Coil Name:	ELQ8.1	Coil Model:	6Q12	PS: Shim Amplifier 892

Magnet Position 8 - 2:

Assembly	ELQ8.2	Assembly Model:	6Q12	Regular quadrupole
Coil Name:	ELQ8.2	Coil Model:	6Q12	PS: Shim Amplifier 892
Coil Name:	ELQ8.2CV	Coil Model:	6QTV12	PS: MCOR12 / 2A

Magnet Position 8 - 3:

Assembly	ELQ8.3	Assembly Model:	6Q12	Regular quadrupole
Coil Name:	ELQ8.3	Coil Model:	6Q12	PS: Shim Amplifier 892
Coil Name:	ELQ8.3CH	Coil Model:	6QTH12	PS: MCOR12 / 2A

Sector: 9

Magnet Position 9 - 1:

Assembly	ELQ9.1	Assembly Model:	6Q12	Regular quadrupole
Coil Name:	ELQ9.1	Coil Model:	6Q12	PS: Shim Amplifier 892

Magnet Position 9 - 2:

Assembly	ELQ9.2	Assembly Model:	6Q12	Regular quadrupole
Coil Name:	ELQ9.2	Coil Model:	6Q12	PS: Shim Amplifier 892
Coil Name:	ELQ9.2CV	Coil Model:	6QTV12	PS: MCOR12 / 2A

Sector: 10

Magnet Position 10 - 1:

Assembly	ELQ10.1	Assembly Model:	6Q12	Regular quadrupole
Coil Name:	ELQ10.1	Coil Model:	6Q12	PS: Shim Amplifier 892

Magnet Position 10 - 2:

Assembly	ELQ10.2	Assembly Model:	6Q12	Regular quadrupole	
Coil Name:	ELQ10.2	Coil Model:	6Q12	PS:	Shim Amplifier 892
Coil Name:	ELQ10.2C	Coil Model:	6QTH12	PS:	MCOR12 / 2A

Sector: 11

Magnet Position 11 - 1:

Assembly	ELQ11.1	Assembly Model:	6Q12	Regular quadrupole	
Coil Name:	ELQ11.1	Coil Model:	6Q12	PS:	Shim Amplifier 892

Magnet Position 11 - 2:

Assembly	ELQ11.2	Assembly Model:	6Q12	Regular quadrupole	
Coil Name:	ELQ11.2	Coil Model:	6Q12	PS:	Shim Amplifier 892
Coil Name:	ELQ11.2C	Coil Model:	6QTH12	PS:	MCOR12 / 2A

Sector: 12

Magnet Position 12 - 1:

Assembly	ELD12.1	Assembly Model:	3D60	60 degree dipole, 20 cm radius	
Coil Name:	ELD12.1	Coil Model:	3D60	PS:	UD320A35V
Coil Name:	ELD12.1CH	Coil Model:	3DT60	PS:	MCOR12 / 6A
Assembly	ELQ12.1	Assembly Model:	6Q12	Regular quadrupole	
Coil Name:	ELQ12.1	Coil Model:	6Q12	PS:	Shim Amplifier 892

Magnet Position 12 - 2:

Assembly	ELQ12.2	Assembly Model:	6Q12	Regular quadrupole	
Coil Name:	ELQ12.2	Coil Model:	6Q12	PS:	Shim Amplifier 892
Coil Name:	ELQ12.2C	Coil Model:	6QTV12	PS:	MCOR12 / 2A

Sector: 13

Magnet Position 13 - 1:

Assembly	ELD13.1	Assembly Model:	3D60	60 degree dipole, 20 cm radius	
Coil Name:	ELD13.1	Coil Model:	3D60	PS:	UD320A35V
Coil Name:	ELD13.1CH	Coil Model:	3DT60	PS:	MCOR12 / 6A
Assembly	ELQ13.1	Assembly Model:	6Q12	Regular quadrupole	
Coil Name:	ELQ13.1	Coil Model:	6Q12	PS:	Shim Amplifier 892
Coil Name:	ELQ13.1C	Coil Model:	6QTH12	PS:	MCOR12 / 2A

Magnet Position 13 - 2:

Assembly	ELQ13.2	Assembly Model:	6Q12	Regular quadrupole
Coil Name:	ELQ13.2	Coil Model:	6Q12	PS: Shim Amplifier 892
Coil Name:	ELQ13.2C	Coil Model:	6QTV12	PS: MCOR12 / 2A

Magnet Position 13 - 3:

Assembly	ELQ13.3	Assembly Model:	6Q12	Regular quadrupole
Coil Name:	ELQ13.3	Coil Model:	6Q12	PS: Shim Amplifier 892

Sector: 14

Magnet Position 14 - 1:

Assembly	ELD14.1	Assembly Model:	3D60	60 degree dipole, 20 cm radius
Coil Name:	ELD14.1	Coil Model:	3D60	PS: UD320A35V
Coil Name:	ELD14.1CH	Coil Model:	3DT60	PS: MCOR12 / 6A
Assembly	ELQ14.1	Assembly Model:	6Q12	Regular quadrupole
Coil Name:	ELQ14.1	Coil Model:	6Q12	PS: Shim Amplifier 892

Magnet Position 14 - 2:

Assembly	ELQ14.2	Assembly Model:	6Q12	Regular quadrupole
Coil Name:	ELQ14.2	Coil Model:	6Q12	PS: Shim Amplifier 892
Coil Name:	ELQ14.2C	Coil Model:	6QTV12	PS: MCOR12 / 2A

Magnet Position 14 - 3:

Assembly	ELQ14.3	Assembly Model:	6Q12	Regular quadrupole
Coil Name:	ELQ14.3	Coil Model:	6Q12	PS: Shim Amplifier 892
Coil Name:	ELQ14.3C	Coil Model:	6QTH12	PS: MCOR12 / 2A

Sector: 15

Magnet Position 15 - 1:

Assembly	ELD15.1	Assembly Model:	3D2	Small compensating dipole
Coil Name:	ELD15.1	Coil Model:	3D2	PS: Shim Amplifier 892
Assembly	ELQ15.1	Assembly Model:	3Q12	Small quadrupole
Coil Name:	ELQ15.1	Coil Model:	3Q12	PS: Shim Amplifier 892

Magnet Position 15 - 2:

Assembly	ELD15.2	Assembly Model:	3D2	Small compensating dipole
Coil Name:	ELD15.2	Coil Model:	3D2	PS: Shim Amplifier 892
Assembly	ELQ15.2	Assembly Model:	3Q12	Small quadrupole
Coil Name:	ELQ15.2	Coil Model:	3Q12	PS: Shim Amplifier 892

Sector: 16

Magnet Position 16 - 1:

Assembly	ELS16.1	Assembly Model:	10S10	Driving to Beam Dump Solenoid
Coil Name:	ELS16.1	Coil Model:	10S10	PS: BOP 50-20GL
Assembly	ELC16.1	Assembly Model:	5D10	Corrector in extraction line
Coil Name:	ELC16.1CH	Coil Model:	5DH10	PS: MCOR12 / 2A
Coil Name:	ELC16.1CV	Coil Model:	5DV10	PS: MCOR12 / 2A
Assembly	ELD16.1	Assembly Model:	6D30	Dipole just before the beam dump
Coil Name:	ELD16.1	Coil Model:	6D30	PS: Shim Amplifier 892

Magnet Position 16 - 2:

Assembly	ELS16.2	Assembly Model:	10S10	Driving to Beam Dump Solenoid
Coil Name:	ELS16.2	Coil Model:	10S10	PS: BOP 50-20GL

Magnet Position 16 - 3:

Assembly	ELS16.3	Assembly Model:	10S10	Driving to Beam Dump Solenoid
Coil Name:	ELS16.3	Coil Model:	10S10	PS: BOP 50-20GL

Magnet Position 16 - 4:

Assembly	ELS16.4	Assembly Model:	10S10	Driving to Beam Dump Solenoid
Coil Name:	ELS16.4	Coil Model:	10S10	PS: BOP 50-20GL

Appendix B
Magnet Circuits by Power Supply Model

UD320A35V, IE Power

1. PS_ELDMain — 60 degree dipole, 20 cm radius

Magnet Name	Magnet Model
ELD6.1	3D60
ELD7.1	3D60
ELD8.1	3D60
ELD12.1	3D60
ELD13.1	3D60
ELD14.1	3D60

Shim Amplifier 892, Danfysik

1. PS_ELD15.1 — Small compensating dipole

Magnet Name	Magnet Model
ELD15.1	3D2

2. PS_ELD15.2 — Small compensating dipole

Magnet Name	Magnet Model
ELD15.2	3D2

3. PS_ELD16.1 — Dipole just before the beam dump

Magnet Name	Magnet Model
ELD16.1	6D30

4. PS_ELD3.1 — 15 degree combined function

Magnet Name	Magnet Model
ELD3.1	7CD15

5. PS_ELD3.2 — 30 degree combined function

Magnet Name	Magnet Model
ELD3.2	7CD30

6. PS_ELD3.3 — 15 degree combined function

Magnet Name	Magnet Model
ELD3.3	7CD15

7. PS_ELD3.4 — 30 degree combined function

Magnet Name	Magnet Model
ELD3.4	7CD30

8 . PS_ELQ10.1 Regular quadrupole

Magnet Name	Magnet Model
ELQ10.1	6Q12

9 . PS_ELQ10.2 Regular quadrupole

Magnet Name	Magnet Model
ELQ10.2	6Q12

10 . PS_ELQ11.1 Regular quadrupole

Magnet Name	Magnet Model
ELQ11.1	6Q12

11 . PS_ELQ11.2 Regular quadrupole

Magnet Name	Magnet Model
ELQ11.2	6Q12

12 . PS_ELQ12.1 Regular quadrupole

Magnet Name	Magnet Model
ELQ12.1	6Q12

13 . PS_ELQ12.2 Regular quadrupole

Magnet Name	Magnet Model
ELQ12.2	6Q12

14 . PS_ELQ13.1 Regular quadrupole

Magnet Name	Magnet Model
ELQ13.1	6Q12

15 . PS_ELQ13.2 Regular quadrupole

Magnet Name	Magnet Model
ELQ13.2	6Q12

16 . PS_ELQ13.3 Regular quadrupole

Magnet Name	Magnet Model
ELQ13.3	6Q12

17 . PS_ELQ14.1 Regular quadrupole

Magnet Name	Magnet Model
ELQ14.1	6Q12

18 . PS_ELQ14.2 Regular quadrupole

Magnet Name	Magnet Model
ELQ14.2	6Q12

19 . PS_ELQ14.3 Regular quadrupole

Magnet Name	Magnet Model
ELQ14.3	6Q12

20 . PS_ELQ15.1 Small quadrupole

Magnet Name	Magnet Model
ELQ15.1	3Q12

21 . PS_ELQ15.2 Small quadrupole

Magnet Name	Magnet Model
ELQ15.2	3Q12

22 . PS_ELQ6.1 Regular quadrupole

Magnet Name	Magnet Model
ELQ6.1	6Q12

23 . PS_ELQ6.2 Regular quadrupole

Magnet Name	Magnet Model
ELQ6.2	6Q12

24 . PS_ELQ6.3 Regular quadrupole

Magnet Name	Magnet Model
ELQ6.3	6Q12

25 . PS_ELQ7.1 Regular quadrupole

Magnet Name	Magnet Model
ELQ7.1	6Q12

26 . PS_ELQ7.2 Regular quadrupole

Magnet Name	Magnet Model
ELQ7.2	6Q12

27 . PS_ELQ7.3 Regular quadrupole

Magnet Name	Magnet Model
ELQ7.3	6Q12

28 . PS_ELQ8.1 Regular quadrupole

Magnet Name	Magnet Model
ELQ8.1	6Q12

29 . PS_ELQ8.2 Regular quadrupole

Magnet Name	Magnet Model
ELQ8.2	6Q12

30 . PS_ELQ8.3 Regular quadrupole

Magnet Name Magnet Model
ELQ8.3 6Q12

31 . PS_ELQ9.1 Regular quadrupole

Magnet Name Magnet Model
ELQ9.1 6Q12

32 . PS_ELQ9.2 Regular quadrupole

Magnet Name Magnet Model
ELQ9.2 6Q12

33 . PS_ELS1.1 High Temp SC solenoid

Magnet Name Magnet Model
ELS1.1 10S10HTS

34 . PS_ELS2.1 Diagnostic solenoid

Magnet Name Magnet Model
ELS2.1 11S10

MCOR12 / 6A, BiRa

1 . PS_ELD12.1CH 60 degree dipole, 20 cm radius

Magnet Name Magnet Model
ELD12.1CH 3DT60

2 . PS_ELD13.1CH 60 degree dipole, 20 cm radius

Magnet Name Magnet Model
ELD13.1CH 3DT60

3 . PS_ELD14.1CH 60 degree dipole, 20 cm radius

Magnet Name Magnet Model
ELD14.1CH 3DT60

4 . PS_ELD6.1CH 60 degree dipole, 20 cm radius

Magnet Name Magnet Model
ELD6.1CH 3DT60

5 . PS_ELD7.1CH 60 degree dipole, 20 cm radius

Magnet Name Magnet Model
ELD7.1CH 3DT60

6 . PS_ELD8.1CH 60 degree dipole, 20 cm radius

Magnet Name	Magnet Model
ELD8.1CH	3DT60

MCOR12 / 2A, BiRa

1 . PS_ELC16.1CH Corrector in extraction line

Magnet Name	Magnet Model
ELC16.1CH	5DH10

2 . PS_ELC16.1CV Corrector in extraction line

Magnet Name	Magnet Model
ELC16.1CV	5DV10

3 . PS_ELC2.1CH Air coils around 6-way cross

Magnet Name	Magnet Model
ELC2.1CH	5DH10

4 . PS_ELC2.1CV Air coils around 6-way cross

Magnet Name	Magnet Model
ELC2.1CV	5DV10

5 . PS_ELD3.1CH 15 degree combined function

Magnet Name	Magnet Model
ELD3.1CH	7CDHT15

6 . PS_ELD3.1Q 15 degree combined function

Magnet Name	Magnet Model
ELD3.1Q	7CQ15

7 . PS_ELD3.1X 15 degree combined function

Magnet Name	Magnet Model
ELD3.1X	7CX15

8 . PS_ELD3.2CH 30 degree combined function

Magnet Name	Magnet Model
ELD3.2CH	7CDHT30

9 . PS_ELD3.2Q 30 degree combined function

Magnet Name	Magnet Model
ELD3.2Q	7CQ30

10 . PS_ELD3.2X 30 degree combined function

Magnet Name	Magnet Model
ELD3.2X	7CX30

11 . PS_ELD3.3CH 15 degree combined function

	Magnet Name	Magnet Model
	ELD3.3CH	7CDHT15
12 .	PS_ELD3.3Q	15 degree combined function
	Magnet Name	Magnet Model
	ELD3.3Q	7CQ15
13 .	PS_ELD3.3X	15 degree combined function
	Magnet Name	Magnet Model
	ELD3.3X	7CX15
14 .	PS_ELD3.4CH	30 degree combined function
	Magnet Name	Magnet Model
	ELD3.4CH	7CDHT30
15 .	PS_ELD3.4Q	30 degree combined function
	Magnet Name	Magnet Model
	ELD3.4Q	7CQ30
16 .	PS_ELD3.4X	30 degree combined function
	Magnet Name	Magnet Model
	ELD3.4X	7CX30
17 .	PS_ELD5.1CH	1st Extraction dipole
	Magnet Name	Magnet Model
	ELD5.1CH	6DT20
18 .	PS_ELD5.2CH	Compensating chicane
	Magnet Name	Magnet Model
	ELD5.2CH	6DT40
19 .	PS_ELD5.3CH	Compensating chicane
	Magnet Name	Magnet Model
	ELD5.3CH	6DT20
20 .	PS_ELQ10.2CH	Regular quadrupole
	Magnet Name	Magnet Model
	ELQ10.2CH	6QTH12
21 .	PS_ELQ11.2CH	Regular quadrupole
	Magnet Name	Magnet Model
	ELQ11.2CH	6QTH12
22 .	PS_ELQ12.2CV	Regular quadrupole
	Magnet Name	Magnet Model
	ELQ12.2CV	6QTV12

23 . PS_ELQ13.1CH Regular quadrupole

Magnet Name	Magnet Model
ELQ13.1CH	6QTH12

24 . PS_ELQ13.2CV Regular quadrupole

Magnet Name	Magnet Model
ELQ13.2CV	6QTV12

25 . PS_ELQ14.2CV Regular quadrupole

Magnet Name	Magnet Model
ELQ14.2CV	6QTV12

26 . PS_ELQ14.3CH Regular quadrupole

Magnet Name	Magnet Model
ELQ14.3CH	6QTH12

27 . PS_ELQ6.2CV Regular quadrupole

Magnet Name	Magnet Model
ELQ6.2CV	6QTV12

28 . PS_ELQ7.1CH Regular quadrupole

Magnet Name	Magnet Model
ELQ7.1CH	6QTH12

29 . PS_ELQ7.2CV Regular quadrupole

Magnet Name	Magnet Model
ELQ7.2CV	6QTV12

30 . PS_ELQ8.2CV Regular quadrupole

Magnet Name	Magnet Model
ELQ8.2CV	6QTV12

31 . PS_ELQ8.3CH Regular quadrupole

Magnet Name	Magnet Model
ELQ8.3CH	6QTH12

32 . PS_ELQ9.2CV Regular quadrupole

Magnet Name	Magnet Model
ELQ9.2CV	6QTV12

BOP 50-20GL, Kepco

1. PS_ELD5.1-3 — 1st Extraction dipole

Magnet Name	Magnet Model
ELD5.1	6D20
ELD5.2	6D40
ELD5.3	6D20

2. PS_ELS16.1-4 — Driving to Beam Dump Solenoid

Magnet Name	Magnet Model
ELS16.1	10S10
ELS16.2	10S10
ELS16.3	10S10
ELS16.4	10S10

3. PS_ELS4.1-2 — Injection line solenoid

Magnet Name	Magnet Model
ELS4.1	11S10
ELS4.2	11S10

4. PS_ELS4.3-4 — Extraction line solenoid

Magnet Name	Magnet Model
ELS4.3	11S10
ELS4.4	11S10

5. PS_ELS5.1-2 — Solenoid after the chicane

Magnet Name	Magnet Model
ELS5.1	11S10
ELS5.2	11S10

Appendix C
AC Power Requirements for Magnet Power Supplies

1. Main Dipole PS - Qty 1 - IE Power

   Output power = 320A x 35V = 11.2 KW
   Input voltage = 480 VAC, 3 ph
   Input current = 20A / ph
   Input power = 16.5 KVA

   This is the only 480V load. All other supplies operate using 120 / 208 VAC, 3 phase power.

2. Solenoid PS - Qty 5 – Kepco

   Output power = 20A x 50V = 1.0 kW
   Input voltage = 208 VAC, 1 ph
   Input current = 8.4A
   Input power = 1.75 KVA
   Distributed equally, three units will cause a line current to be drawn which is the vector sum of the two currents. We have almost two sets of three with the five units.

   I_2 = 14.6A x 2 = 29.2A / phase

3. Main Quad PS - Qty 6 crates (36 regulators) – Danfysik

   Output power = (10A x 15V) x 6 regulators = 900 W / crate
   Input voltage 208 VAC, 3 ph.
   Input current = 3A / ph / crate
   Input power = 1.1 KVA / crate

   I_3 = 3A x 6 crates = 18.0A / phase

4. Corrector PS - Qty 3 crates – BiRa

   The power here is computed in three parts:

   a) Genesys bulk supply
      Output power = 30A x 50V = 1.5 kW
      Input voltage = 120 VAC, 1 ph
      Input current = 19A
      Input power = 2.3 KVA

      These three supplies could also be run at 208 VAC. If we did that, after connecting one unit on each of the line voltages, the 208 VAC line currents would be the same as the 120 VAC configuration.

   b) Housekeeping power supply (+/-15, +5) for crate.
      Input power = 2A at 120 VAC = 240 KVA

   c) Crate coolers
      Input power = 2A at 120 VAC = 240 KVA

   Each of these three crates hangs on one phase and draws:

I_4 = 19A + 2A + 2A = 23A

With all power supplies using 208 VAC operating at full output power, we'd need:

$I_{TOT} = I_2 + I_3 + I_4$ = 29.2A + 18.0A + 23.0A = 70.2 Amps / phase

Of course we're not running full out. I'd say a nice conservative estimate would be 80% of max or 56.2 Amps / phase. The corresponding power is:

P_{TOT} = 208 x e3 x 70.2 = 25.3 KVA (120 / 208 VAC, 3 phase)

In a similar fashion, if we estimate the actual 480 VAC load at 80% of the maximum, we'd require:

P_{TOT} = 0.8 x 16.5 = 13.2 KVA (480 VAC, 3 phase)