

Energy Recovery Linac: Power Supplies

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R&D ERL: Power Supplies

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R&D ERL – Power Supplies
R. Lambiase
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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.

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.



Figure 1. IE Power & Kepco Supplies

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.

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.

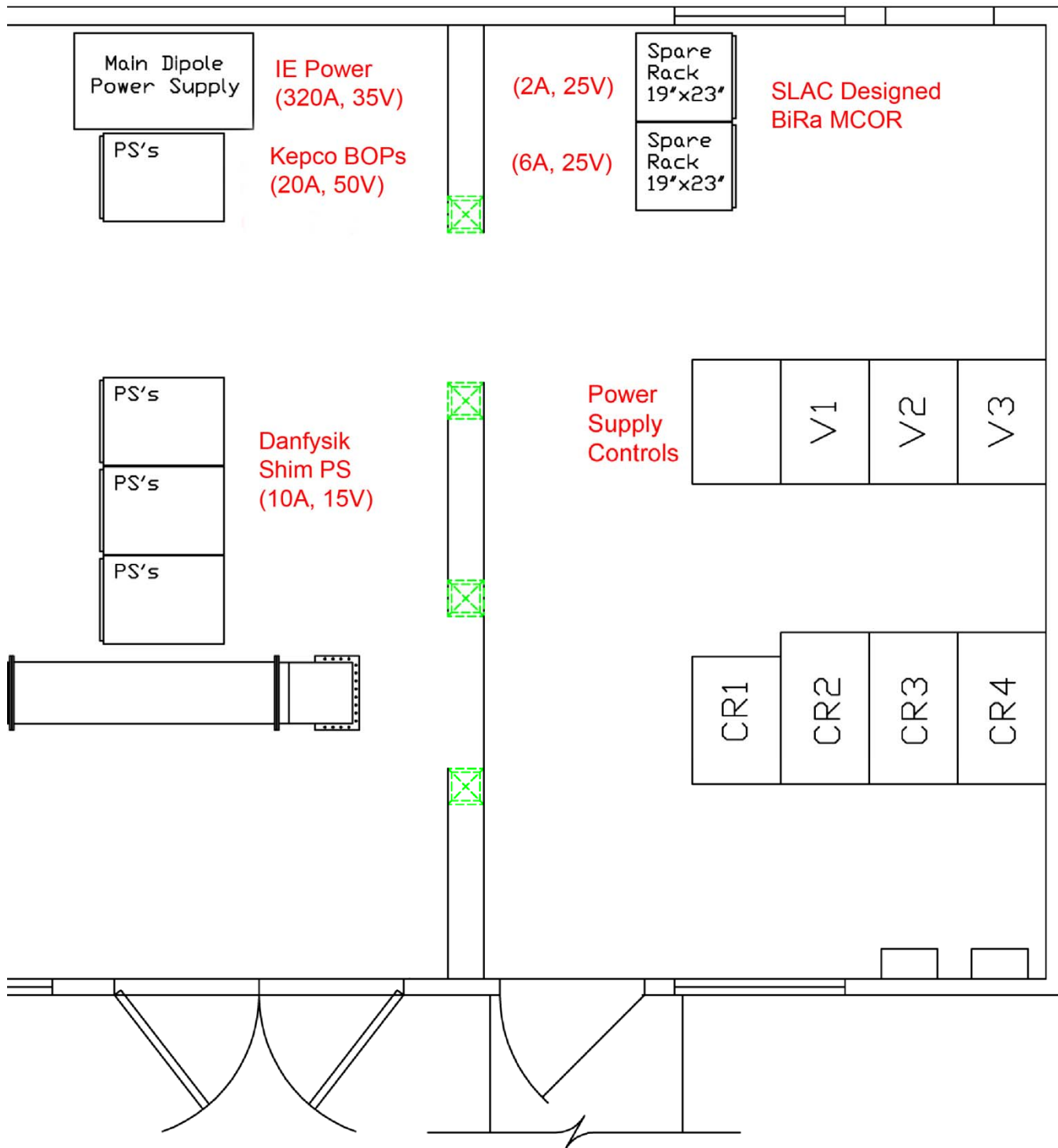


Figure 3. BiRa Power Supplies

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)

(2A, 25V)

Spare
Rack
19"x23"

SLAC Designed
BiRa MCOR

PS's

Kepeco BOPs
(20A, 50V)

(6A, 25V)

Spare
Rack
19"x23"

PS's

Danfysik
Shim PS
(10A, 15V)

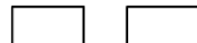
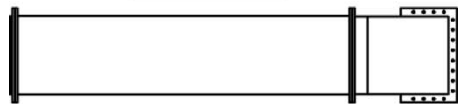
Power
Supply
Controls

V1 V2 V3

PS's

PS's

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
<i>Magnet Name</i>	Magnet Model
<i>ELD6.1</i>	3D60
<i>ELD7.1</i>	3D60
<i>ELD8.1</i>	3D60
<i>ELD12.1</i>	3D60
<i>ELD13.1</i>	3D60
<i>ELD14.1</i>	3D60

Shim Amplifier 892, Danfysik

1 . PS_ELD15.1	Small compensating dipole
<i>Magnet Name</i>	Magnet Model
<i>ELD15.1</i>	3D2
2 . PS_ELD15.2	Small compensating dipole
<i>Magnet Name</i>	Magnet Model
<i>ELD15.2</i>	3D2
3 . PS_ELD16.1	Dipole just before the beam dump
<i>Magnet Name</i>	Magnet Model
<i>ELD16.1</i>	6D30
4 . PS_ELD3.1	15 degree combined function
<i>Magnet Name</i>	Magnet Model
<i>ELD3.1</i>	7CD15
5 . PS_ELD3.2	30 degree combined function
<i>Magnet Name</i>	Magnet Model
<i>ELD3.2</i>	7CD30
6 . PS_ELD3.3	15 degree combined function
<i>Magnet Name</i>	Magnet Model
<i>ELD3.3</i>	7CD15
7 . PS_ELD3.4	30 degree combined function
<i>Magnet Name</i>	Magnet Model
<i>ELD3.4</i>	7CD30

8 . PS_ELQ10.1	Regular quadrupole
<i>Magnet Name</i>	Magnet Model
<i>ELQ10.1</i>	6Q12
9 . PS_ELQ10.2	Regular quadrupole
<i>Magnet Name</i>	Magnet Model
<i>ELQ10.2</i>	6Q12
10 . PS_ELQ11.1	Regular quadrupole
<i>Magnet Name</i>	Magnet Model
<i>ELQ11.1</i>	6Q12
11 . PS_ELQ11.2	Regular quadrupole
<i>Magnet Name</i>	Magnet Model
<i>ELQ11.2</i>	6Q12
12 . PS_ELQ12.1	Regular quadrupole
<i>Magnet Name</i>	Magnet Model
<i>ELQ12.1</i>	6Q12
13 . PS_ELQ12.2	Regular quadrupole
<i>Magnet Name</i>	Magnet Model
<i>ELQ12.2</i>	6Q12
14 . PS_ELQ13.1	Regular quadrupole
<i>Magnet Name</i>	Magnet Model
<i>ELQ13.1</i>	6Q12
15 . PS_ELQ13.2	Regular quadrupole
<i>Magnet Name</i>	Magnet Model
<i>ELQ13.2</i>	6Q12
16 . PS_ELQ13.3	Regular quadrupole
<i>Magnet Name</i>	Magnet Model
<i>ELQ13.3</i>	6Q12
17 . PS_ELQ14.1	Regular quadrupole
<i>Magnet Name</i>	Magnet Model
<i>ELQ14.1</i>	6Q12
18 . PS_ELQ14.2	Regular quadrupole
<i>Magnet Name</i>	Magnet Model
<i>ELQ14.2</i>	6Q12

19 . PS_ELQ14.3	Regular quadrupole
<i>Magnet Name</i> ELQ14.3	Magnet Model 6Q12
20 . PS_ELQ15.1	Small quadrupole
<i>Magnet Name</i> ELQ15.1	Magnet Model 3Q12
21 . PS_ELQ15.2	Small quadrupole
<i>Magnet Name</i> ELQ15.2	Magnet Model 3Q12
22 . PS_ELQ6.1	Regular quadrupole
<i>Magnet Name</i> ELQ6.1	Magnet Model 6Q12
23 . PS_ELQ6.2	Regular quadrupole
<i>Magnet Name</i> ELQ6.2	Magnet Model 6Q12
24 . PS_ELQ6.3	Regular quadrupole
<i>Magnet Name</i> ELQ6.3	Magnet Model 6Q12
25 . PS_ELQ7.1	Regular quadrupole
<i>Magnet Name</i> ELQ7.1	Magnet Model 6Q12
26 . PS_ELQ7.2	Regular quadrupole
<i>Magnet Name</i> ELQ7.2	Magnet Model 6Q12
27 . PS_ELQ7.3	Regular quadrupole
<i>Magnet Name</i> ELQ7.3	Magnet Model 6Q12
28 . PS_ELQ8.1	Regular quadrupole
<i>Magnet Name</i> ELQ8.1	Magnet Model 6Q12
29 . PS_ELQ8.2	Regular quadrupole
<i>Magnet Name</i> ELQ8.2	Magnet Model 6Q12

30 . PS_ELQ8.3	Regular quadrupole
<i>Magnet Name</i> ELQ8.3	Magnet Model 6Q12
31 . PS_ELQ9.1	Regular quadrupole
<i>Magnet Name</i> ELQ9.1	Magnet Model 6Q12
32 . PS_ELQ9.2	Regular quadrupole
<i>Magnet Name</i> ELQ9.2	Magnet Model 6Q12
33 . PS_ELS1.1	High Temp SC solenoid
<i>Magnet Name</i> ELS1.1	Magnet Model 10S10HTS
34 . PS_ELS2.1	Diagnostic solenoid
<i>Magnet Name</i> ELS2.1	Magnet Model 11S10

MCOR12 / 6A, BiRa

1 . PS_ELD12.1CH	60 degree dipole, 20 cm radius
<i>Magnet Name</i> ELD12.1CH	Magnet Model 3DT60
2 . PS_ELD13.1CH	60 degree dipole, 20 cm radius
<i>Magnet Name</i> ELD13.1CH	Magnet Model 3DT60
3 . PS_ELD14.1CH	60 degree dipole, 20 cm radius
<i>Magnet Name</i> ELD14.1CH	Magnet Model 3DT60
4 . PS_ELD6.1CH	60 degree dipole, 20 cm radius
<i>Magnet Name</i> ELD6.1CH	Magnet Model 3DT60
5 . PS_ELD7.1CH	60 degree dipole, 20 cm radius
<i>Magnet Name</i> ELD7.1CH	Magnet Model 3DT60
6 . PS_ELD8.1CH	60 degree dipole, 20 cm radius

<i>Magnet Name</i> ELD8.1CH	Magnet Model 3DT60
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MCOR12 / 2A, BiRa

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|---------------------------------|------------------------------|
| 1 . PS_ELC16.1CH | Corrector in extraction line |
| <i>Magnet Name</i>
ELC16.1CH | Magnet Model
5DH10 |
| 2 . PS_ELC16.1CV | Corrector in extraction line |
| <i>Magnet Name</i>
ELC16.1CV | Magnet Model
5DV10 |
| 3 . PS_ELC2.1CH | Air coils around 6-way cross |
| <i>Magnet Name</i>
ELC2.1CH | Magnet Model
5DH10 |
| 4 . PS_ELC2.1CV | Air coils around 6-way cross |
| <i>Magnet Name</i>
ELC2.1CV | Magnet Model
5DV10 |
| 5 . PS_ELD3.1CH | 15 degree combined function |
| <i>Magnet Name</i>
ELD3.1CH | Magnet Model
7CDHT15 |
| 6 . PS_ELD3.1Q | 15 degree combined function |
| <i>Magnet Name</i>
ELD3.1Q | Magnet Model
7CQ15 |
| 7 . PS_ELD3.1X | 15 degree combined function |
| <i>Magnet Name</i>
ELD3.1X | Magnet Model
7CX15 |
| 8 . PS_ELD3.2CH | 30 degree combined function |
| <i>Magnet Name</i>
ELD3.2CH | Magnet Model
7CDHT30 |
| 9 . PS_ELD3.2Q | 30 degree combined function |
| <i>Magnet Name</i>
ELD3.2Q | Magnet Model
7CQ30 |
| 10 . PS_ELD3.2X | 30 degree combined function |
| <i>Magnet Name</i>
ELD3.2X | Magnet Model
7CX30 |
| 11 . PS_ELD3.3CH | 15 degree combined function |

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

23 . PS_ELQ13.1CH	Regular quadrupole
<i>Magnet Name</i>	Magnet Model
<i>ELQ13.1CH</i>	6QTH12
24 . PS_ELQ13.2CV	Regular quadrupole
<i>Magnet Name</i>	Magnet Model
<i>ELQ13.2CV</i>	6QTV12
25 . PS_ELQ14.2CV	Regular quadrupole
<i>Magnet Name</i>	Magnet Model
<i>ELQ14.2CV</i>	6QTV12
26 . PS_ELQ14.3CH	Regular quadrupole
<i>Magnet Name</i>	Magnet Model
<i>ELQ14.3CH</i>	6QTH12
27 . PS_ELQ6.2CV	Regular quadrupole
<i>Magnet Name</i>	Magnet Model
<i>ELQ6.2CV</i>	6QTV12
28 . PS_ELQ7.1CH	Regular quadrupole
<i>Magnet Name</i>	Magnet Model
<i>ELQ7.1CH</i>	6QTH12
29 . PS_ELQ7.2CV	Regular quadrupole
<i>Magnet Name</i>	Magnet Model
<i>ELQ7.2CV</i>	6QTV12
30 . PS_ELQ8.2CV	Regular quadrupole
<i>Magnet Name</i>	Magnet Model
<i>ELQ8.2CV</i>	6QTV12
31 . PS_ELQ8.3CH	Regular quadrupole
<i>Magnet Name</i>	Magnet Model
<i>ELQ8.3CH</i>	6QTH12
32 . PS_ELQ9.2CV	Regular quadrupole
<i>Magnet Name</i>	Magnet Model
<i>ELQ9.2CV</i>	6QTV12

BOP 50-20GL, Kepco

1 . PS_ELD5.1-3	1st Extraction dipole
<i>Magnet Name</i>	Magnet Model
<i>ELD5.1</i>	6D20
<i>ELD5.2</i>	6D40
<i>ELD5.3</i>	6D20
2 . PS_ELS16.1-4	Driving to Beam Dump Solenoid
<i>Magnet Name</i>	Magnet Model
<i>ELS16.1</i>	10S10
<i>ELS16.2</i>	10S10
<i>ELS16.3</i>	10S10
<i>ELS16.4</i>	10S10
3 . PS_ELS4.1-2	Injection line solenoid
<i>Magnet Name</i>	Magnet Model
<i>ELS4.1</i>	11S10
<i>ELS4.2</i>	11S10
4 . PS_ELS4.3-4	Extraction line solenoid
<i>Magnet Name</i>	Magnet Model
<i>ELS4.3</i>	11S10
<i>ELS4.4</i>	11S10
5 . PS_ELS5.1-2	Solenoid after the chicane
<i>Magnet Name</i>	Magnet Model
<i>ELS5.1</i>	11S10
<i>ELS5.2</i>	11S10

Appendix C

AC Power Requirements for Magnet Power Supplies

1. Main Dipole PS - Qty 1 - IE Power

Output power = $320A \times 35V = 11.2 \text{ KW}$
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 = $20A \times 50V = 1.0 \text{ kW}$
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.

$$I_2 = 14.6A \times 2 = 29.2A / \text{phase}$$

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

Output power = $(10A \times 15V) \times 6 \text{ regulators} = 900 \text{ W / crate}$
Input voltage 208 VAC, 3 ph.
Input current = 3A / ph / crate
Input power = 1.1 KVA / crate

$$I_3 = 3A \times 6 \text{ crates} = 18.0A / \text{phase}$$

4. Corrector PS - Qty 3 crates – BiRa

The power here is computed in three parts:

- a) Genesys bulk supply
Output power = $30A \times 50V = 1.5 \text{ kW}$
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:

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

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:

$$P_{TOT} = 208 \times \sqrt{3} \times 70.2 = 25.3 \text{ KVA} \quad (120 / 208 \text{ VAC, 3 phase})$$

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

$$P_{TOT} = 0.8 \times 16.5 = 13.2 \text{ KVA} \quad (480 \text{ VAC, 3 phase})$$