SPEAR 3 Overviews

AC Distribution System - Marjorie Widmeyer

Magnet Power Supplies - Paul Bellomo

August 2003
AC Distribution System

• **Purpose**
  - Provide required power to power supplies and support equipment
  - Allow power supplies to be easily isolated for shutdown and maintenance
  - Separate control and utility supplies

• **Scope**
  - AC Distribution – one line overview
  - Lock out/Tag out
  - PPS
SPEAR 3 AC Distribution and layout drawings:
http://www.slac.stanford.edu/grp/md/dcon/draw/draw.html

The drawing number blocks are:

- **ID-439-720-20**  
  Substation 507 HV Distribution  
  Single Line Diagram

- **444-500-00 to 444-500-99**  
  B118 Layouts

- **444-690-00 to 444-690-99**  
  B118 AC Distribution
AC Distribution System

B117 Control Room

Substation 507
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4B-155
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4B-156
AC Distribution System

12 KV AC Supply

4B-156

480 VAC Supply

4B-155

Substation

507

SWBD - 01

SWBD - 02

MCC 02A Dipole Power Supply
MCC 02B Dipole Power Supply
MCC 01 Corrector Supplies, Skewquad, Dipole Trim, Insertion Device Trims
MCC 03 QF: B118-01 to 06
               OD: B118-31 to 36
               OF: OFC Strings
MCC 04 SD, SF, SD/FM Strings
               QFX to QFZ
               BTS TSP and Pulsers
PNL 02 Utility
PNL 01 Control

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Some Details

• The total power draw of all the SPEAR 3 magnet power supplies is about 2,300 kVA. This is about 33% less than SPEAR2.
  
  • No electromagnetic wigglers
  
  • Magnets have copper windings instead of aluminum
  
  • Power supplies are more efficient
  
  • Dipole power supply at about 1,100kVA takes almost ½ of this power
  
  • The load is roughly balanced on 4B-155 and 4B-156 and on Switchboards 4PB118-SWBD-01 and 4PB118-SWBD-02
AC Distribution System

Lock Out/Tag Out

- Lock off all B118 power supplies via 5 MCC main breakers
- Lock off an entire rack of power supplies at the MCCs
- Lock off individual power supplies

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**AC Distribution System**

- **PPS Controls Contactor on each MCC**
- **Contactor Control**
  - Local on off switch
  - PPS Chain A & B
  - Emergency Off – Dipole Only
- Door covering contactors is mechanically interlocked with the door for the main breaker of the MCC to prevent opening the contactor door when the Main Breaker is closed
AC Distribution System
MCC – IQ Analyzer

- IQ Analyzer Displays:
  - Current
  - Voltage
  - Power system and phase (A, B, C), Real Power (Watts), Reactive Power (vars), Apparent Power (VA),
  - Power Factor
  - Frequency
  - % Total Harmonic Distortion
- Information available on line in the future
**AC Distribution System**

Utility Power
- Beige power strip
  - Supplies power to all fans
- Quad-receptacle in each power supply rack

Control Power
- Blue power strip

Lighting
- Power from PPA Circuit 2, 4, 6
Topics

1. Purpose and Scope
2. B118 Layout
3. Some Generalities
4. Electrical Interlocks
5. Unipolar Power supplies
   a. Dipole
   b. Large (free-standing)
   c. Intermediate (rack-mounted)
   d. Unipolar Control
6. Bipolar Power Supplies
   a. Control for Bipolars
7. Pulsed Power Supplies
   a. Control for Pulsed
1. Purpose and Scope

Purpose

*Power Supplies convert raw, unregulated AC to precise, controlled and regulated DC for continuous current and pulsed current magnets*

Scope

*New SPEAR 3 magnet power supplies in B118*
3. Some Generalities

Reference Drawings

- **SPEAR 3 power supply drawings are available as TIFFs from**

- **The drawing number blocks are:**
  
  444-500-00 to 444-500-99  **B118 Layouts**  S3-0781
  
  444-600-00 to 444-639-99  **Unipolar**  S3-0781
  
  444-640-00 to 444-654-99  **Bipolar**  S3-0782
  
  444-655-00 to 444-659-99  **Pulsed**  S3-0783
  
  444-670-00 to 444-670-99  **BitBus Control**  S3-0784
  
  444-685-00 to 444-689-00  **Racks/Accessories**  S3-0785
3. Some Generalities

- Little local control. Operation is computer-based

- Air-cooled – Exceptions Dipole Bulk Power Supply, Dipole Chopper Modules, SD, SF with valves / instrumentation above each power supply

- All switchmode (high frequency regulation)

- Output rating $\leq 5kW$ are 208VAC, $> 5kW$ are 480VAC, no 4160V

- 480V/208V and 120V control power sources to each power system
3. Some Generalities

Control

- All current sources, except Dipole Bulk, bipolar bulk - these are voltage regulated sources
- All unipolar use BitBus - 1 controller per
- Bipolars are Ethernet based - 1 controller per 8
- Pulsers are GPIB / PLC RS5000 based

Current Stability

- Dipole 50ppm (3ppm / °C) diurnal stability
- Quadrupoles 100ppm (6ppm / °C) diurnal stability
- Sextupoles, Correctors 500ppm (30ppm / °C)
### 3. Some Generalities

<table>
<thead>
<tr>
<th>Local Control</th>
<th>Local Readback</th>
</tr>
</thead>
<tbody>
<tr>
<td>On / off via circuit breaker</td>
<td>Output voltage</td>
</tr>
<tr>
<td>Output current limit</td>
<td>Output current</td>
</tr>
<tr>
<td></td>
<td>Power supply faults</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Remote Control</th>
<th>Remote Readback</th>
</tr>
</thead>
<tbody>
<tr>
<td>On / off</td>
<td>Power supply on / off</td>
</tr>
<tr>
<td>Output current</td>
<td>Output voltage</td>
</tr>
<tr>
<td></td>
<td>Output currents 1 &amp; 2</td>
</tr>
<tr>
<td></td>
<td>Power supply fault</td>
</tr>
<tr>
<td></td>
<td>Magnet O/T via MPS fault</td>
</tr>
<tr>
<td></td>
<td>Ground current fault</td>
</tr>
<tr>
<td></td>
<td>Ambient temp</td>
</tr>
</tbody>
</table>
4. Electrical Interlocks

• **PPS turns all off. Interface in AC distribution system, except septum**

• **All are enclosed. Rack doors lockable but not interlocked. Exceptions Dipole Bulk, the Dipole Chopper Module Rack, 6 Large (QD, QF, QFC, QFC, SD and SF) and 3 Kicker Pulsers**

• **MPS (Klixons) - BitBus controllers interface for Unipolars. Fault trips only the affected power supply**

• **MPS (Klixons) - Bulk PS interfaces for Bipolars. Corrector O/T trips off bulk and 8 bipolars**

• **No MPS interface for titanium sublimation pumps (TSPs) or injection kickers**

• **No accessible energy storage – exceptions are Dipole Bulk, Dipole Chopper Module Racks, 6 Large and 3 Kicker Pulsers**
5. Unipolar Power Supplies

Dipole Transformer
2- 600kVA, 480V:600V
B118-TR1

Dipole Bulk Power Supply
1300V, 775A, 1000kW
B118-PS7

Dipole Chopper Modules
4 - 1200V, 775A, 930kW
B118-47 & -48
5. Unipolar Power Supplies

Dipole Power Supply

• 36 series-connected dipole magnets spaced around the ring

• Δ-Y 1200kVA, 12 pulse to reduce line harmonics

• 4 buck regulators (choppers)

• Three AC power sources
  480V Δ, 480V Y, 120V

• For magnet names and locations
  ID-444-500-05 / EI-444-610-00
5. Unipolar Power Supplies
Dipole Bulk Power Supply Diagnostics

Vo (Volts)  Io (Amps)  Ig (mA)

 XXXX    XXX    XXX

Faults
- AC overcurrent (Red)
- Input φ loss (Red)
- Bridge/FW Diode heatsink (Red)
- Water Flow Low (Red)
- Cabinet Temp/Fan failure (Red)
- Door Open (Red)
- Smoke Detector (Red)
- Output fuse blown (Red)
- DC Overcurrent (Red)
- DC Overvoltage (Red)
- Push to Test LEDs
- PS Interlock Reset

Status
- Main AC on (Gm)
- Choppers Ready (Green)
- PS Ready (Gm)
- DC On (Red)

Voltage Monitor Ports
- Bridge 1
  - Unfiltered V
  - Filtered V
- Bridge 2
  - Unfiltered
  - Filtered V

Output Voltage Adjust

Emergency Off

3-position switch
+ to -  com
+ com -

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5. Unipolar Power Supplies

Dipole PS Chopper Module Controller - SLAC

- Controls operation of series and parallel-connected chopper modules
- No front panel controls or adjustments
5. Unipolar Power Supplies
Dipole Power Supply Schematic

- Diamonds represent BNC diagnostic ports
- Circles represent isolation amps to front panel meters / interlocks
- Diamonds represent isolation amps to front panel meters / interlocks
- All Power Supply Interlocks *
- * Indicates interlock/alarm

- Fans *
- Blown fuse (typ) *
- Smoke Detector *
- Temp Interlock *
- Overcurrent *
- Transductor Head
- OverVoltage *
- Computer
- BitBus Chassis
- MPS Interlock from magnet load
- Choppers ready - 2 inputs from Chopper Controllers
- Synch signal to Chopper Controllers - 2 outputs
- Enerpro Board
- Isolation Amplifier (typ)
- Gate Trigger (Typ)
- Overcurrent *
- Blown fuse (typ) *
- Current shunt (typ)
- Water Flow Interlock *
- Phase Interlock *
- Temp Interlock *
- Overcurrent *
- Transductor Head
- CT (Typ)
- AC
- AC
- Overcurrent *
- 100 Ω ground current sense to power supply controller
- 480 VAC Transformer By Purchaser
- 120VAC By Purchaser
- 600 VAC By Purchaser

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5. Unipolar Power Supplies

Dipole Power Supply Schematic

Bulk Power Supply and PS Controller

Input
AC
Δ
2-1/C500kcmil/φ

1/C500kcmil (typ)

Choppers READY
Synchronizing Signals

Door Switches (typ)

+ Chopper

- Chopper

Chopper Controller 1

Chopper Controller 2

36 Series-Connected Dipole Magnets

DC Output +

Input
AC
Y
2-1/C500kcmil/φ

Com

DC Output +

DC Output -

2-1/C500kcmil/φ
5. Unipolar Power Supplies

- 480V / 120V breakers
- BitBus controller
- Large Power Supplies – IE Power
  - 6 each in a free-standing cabinet
  - QD 70 kW for 6 Quadrant 1 magnets
  - QF 70 kW for 6 Quadrant 1 magnets
  - QFC 70 kW for 7 North Arc magnets
  - QFC 70 kW for 7 South Arc magnets
  - SD 135 kW for 28 Ring magnets
  - SF 135 kW for 28 Ring magnets
5. Unipolar Power Supplies
Large Power Supply Diagnostics

Power Supply Interlocks
- Loss of phase or low AC (Red)
- DC Overcurrent (Red)
- DC Overvoltage (Red)
- Ground Current Limit (Red)
- Air Flow Restricted (Red)
- Cabinet Overtemp (Red)
- Cabinet Door Open (Red)

Voltage And Current Monitor
- Coolant Water Overtemperature (Red)
- Current Limit Active (Yellow)

Push to Test LED's

Emergency OFF Switch

PS Interlock Reset

Ports
- V1A
- V2A
- V3A
- V4A
- V1B
- V2B
- V3B
- V4B

Vo (Volts)
- XXX

Io (Amps)
- XXX

Ig (mA)
- XXX

Output Current Limit

Vo (Volts) Io (Amps) Ig (mA)
5. Unipolar Power Supplies

Large Power Supply Schematic

Power Supply Controller By Seller

SLAC MPS removes ON command if magnet overheats

Desired Current Setpoint From SLAC Computer

Error Amp

Programming Voltage

SLAC Bitbus Chassis

Redundant Current Monitor

Monitor ZF Transductor

To Magnet Load

Feedback ZF Transductor

120 VAC By Purchaser

480 VAC By Purchaser
## 5. Unipolar Power Supplies

### Intermediate Power Supplies

<table>
<thead>
<tr>
<th>Magnet Family</th>
<th>Magnet Quantity</th>
<th>Magnet Location</th>
<th>Power Supply Quantity</th>
<th>Notes</th>
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<tbody>
<tr>
<td>B7H</td>
<td>1</td>
<td>SPEAR side of BTS</td>
<td>2</td>
<td>2 in series</td>
</tr>
<tr>
<td>B8V</td>
<td>1</td>
<td>SPEAR side of BTS</td>
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<td>2 in series</td>
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<tr>
<td>Q8</td>
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<td>SPEAR side of BTS</td>
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<td></td>
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<tr>
<td>Q9</td>
<td>1</td>
<td>SPEAR side of BTS</td>
<td>1</td>
<td></td>
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<tr>
<td>B9V Septum</td>
<td>1</td>
<td>Ring</td>
<td>1</td>
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<tr>
<td>QD</td>
<td>20</td>
<td>Ring</td>
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<td>QF</td>
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<td>Ring</td>
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<td>TSP</td>
<td>72</td>
<td>66 Ring 6 in SS</td>
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<td>QDX</td>
<td>4</td>
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<td>2 in series</td>
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<td><strong>65</strong></td>
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</tbody>
</table>
5. Unipolar Power Supplies

Intermediate Power Supplies
- 2.5 kW, 5.0 kW, 10 kW, 15 kW, 22.5 kW
- IE Power

Typical BitBus Controller

Typical power supply quantity in rack
- 6 - 2.5 kW, 5 kW
- 4 - 10 kW, 15 kW
- 2 – 22.5 kW
5. Unipolar Power Supplies

Intermediate Power Supplies

- Standard 3 Φ 480V or 208V, 150A feed to every power supply rack
- Individual rack and PS circuit breakers are 30A
- Rack breakers are pad-lockable and fault-current rated
- Power supply breakers are on/off only and do not have trip elements
5. Unipolar Power Supplies

Intermediate Power Supplies - minimal front panel control
5. Unipolar Power Supplies

Intermediate PS - Titanium Sublimation Pumps (TSPs)

- Used to pump chemically reactive, getterable gases, such as H\textsubscript{2}, H\textsubscript{2}O, CO, N\textsubscript{2}, O\textsubscript{2}, CO\textsubscript{2}. Titanium is effective, easily sublimed, and inexpensive.

- Have high pumping speeds, typically 10 l/sec/cm\textsuperscript{2}.

- Long-life filaments are 85% titanium and 15% molybdenum
5. Unipolar Power Supplies

- 72 TSPs, 66 in ring, 6 in SS
- 4 operating power supplies – 5th spare
- 5 switching chassis, 16 channels each
- PS control / read-back is BitBus
- Switching chassis control / readback VME (B118-29)
- Operate 1 TSP per PS (quadrant)
- Automatic remote sequential switching with manual possibility
- No ground fault detection / protection
- Possible software PS inhibit if vacuum corrupted
5. Unipolar Power Supplies

Intermediate Power Supply

Control Power

Gate Drivers

Programming Voltage

Desired Current Setpoint From Computer

Error Amp

Redundant Current Monitor

BitBus Chassis

MPS removes ON command if magnet overheats

Error Amp

Monitor Transductor

To Magnet Load

Feedback Transductor

Control Loop

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5. Unipolar Power Supplies

- Precision, ultra-stable BitBus Controller
- Designed by Dave MacNair
- Computer - PS and PS - computer communicator
- Feedback loop
- MPS interface connector on rear panel

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5. Unipolar Power Supplies

- Power supplies are voltage regulated
- SLAC/SSRL adds external current regulation

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5. Unipolar Power Supplies

Danfysik Current Transductors

Dipole power supply 1000A transductors
- Bulk Power Supply
- Chopper Module Rack

Two transductors per power supply
- Current feedback loop
- Verification

150A / 600A transductors all other unipolar power supplies
6. Bipolar Power Supplies

- 30A, 50V “MCOR30”
- Designed by Greg Leyh of PCD
- 108 H & V correctors
- 14 Skewquads
- 15 Insertion Device Trims
- 1 switched Quadrupole Modulation System (QMS)
- 1 Dipole Trim
- 138 total power supplies
- 168 accommodation

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6. Bipolar Power Supplies

- 3 crates in a rack
- 1 bulk power supply per crate
- Bulk is a voltage source. Set voltage manually
- Bulk local V and I analog meters
- No bulk remote control or read-backs
- Bulk is MPS interface
6. Bipolar Power Supplies

- 50V, 30A rating
- Up to 8 in a crate
- L to R: Slots 00, 0, 1, 2, 3, 4, 5, 6, 7
- Left most slot (00) is a new 8-channel Ethernet-based 100Mbps controller for remote control

MCOR30 in crate
6. Bipolar Power Supplies
7. Pulsed Power Supplies

- 2 SRS Trigger generators – input from timing system and GPIB interface for trigger delay and pulse width adjustments
- PLC RS5000 interface-turn on/off, interlock information, set Vo

- 3 injection kicker pulsers
- 3 magnets Quad 1, Sectors 3 and 4
  - K1, K3 1.2m 13kV, 2400A
  - K2 0.6m 7kV, 2600A
- Pulse < 780nS. 10 Hz
7. Pulsed Power Supplies

Panel for local magnet current read-backs via CT and tie to Jorgensen digitizers.

Pulse capacitor charger power supplies

K1 B118-16
K2 B118-17
K3 B118-18
7. Pulsed Power Supplies

- New solid-state, no PFN or thyatron
- Low maintenance, low jitter, high reliability
7. Pulsed Power Supplies

Magnet I VS Time

2600A

600nS
7. Pulsed Power Supplies

SSRL Induction Kicker
10 Sections
2kV 3000A each
200nsec rise time
Happy Operations!