



TO: Interested and Responsible Parties

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FROM: Jim Craft, PSOS Deputy Maintenance Manager, PSOW Group Leader

SUBJECT: Ground Current Troubleshooting and Repair

The only convention we have at SLAC is that no two systems with the same intrinsic function will ever be the same.

How are SLAC Magnets Driven and Why is Ground Current a Potential Problem?

1. Individually driven magnets.
2. Series driven magnet strings with individual electromagnetic trimming power sources.
3. Series driven magnet strings with hardwired bypass trimming driver chassis.
4. Series driven magnet strings with individual hardwired booster trim power supplies.
5. Parallel driven magnets with individual series booster trim power supplies.
6. Individually driven magnets with individual hardwired booster trim power supplies .

In almost all configurations, SLAC magnets are floating with respect to ground such that no magnet current uses ground as a circuit path.

When magnets, magnet cables or components of the power supplies that drive magnets become grounded, there are two main concerns:

1. The electromagnet function expected of the magnet(s) may be diminished causing orbit/lattice deviations/instabilities adverse to the experiment beam.
2. Power supply current flowing outside the designed circuit path may be causing arcing or overheating in machine components that could lead to fire or component damage.

We want to be aware when this fault condition is occurring so we install resistive devices between the output of the power supply and ground to sense a ground in the form of current flow which leads to voltage drop across the device.

Types of Ground Current Monitoring Circuits (Including Resistor/Shunt Type and Location, Control & Monitor Chassis Type)

1. 100 ohm resistance connected between the power supply negative buss and ground.
 - A. Standard EMHP Magnet String: Uses one 100 ohm, 50 watt wire-wound resistor.

1. EMHP Control and Interface Chassis: Located inside controller chassis.
 2. SLC Power Supply Regulator/Controller chassis: Attached to power supply negative buss.
 - B. LINAC QUADS using bypass for individual magnet flux adjustment: Uses EMHP Control and Interface Chassis as described above hooked into the Quad Kink Box in the middle of the magnet string (sectors 5–9).
 - C. LINAC QUADS using booster power supplies for individual magnet flux adjustment: Uses one 250 ohm 225 watt wire-wound resistor located inside the power supply connected to the middle of the power supply pre-load/bleeder (sectors 10-29).
 - D. Klystron Focus Magnet EMHP: Uses a 50A=100MV (2 mohm) shunt bar connected to the power supply negative buss to ground (Sector 0 and odd sectors thereafter).
- Note: LINAC QUAD and Klystron Focus Magnet Power supplies both use EMHP 200V-300A. The configuration was not mutually usable. A modification made it so. Details are part of this presentation.
- E. Low Voltage Controller: Uses one “curly-cue” 5A=100 MV (20mohm) shunt attached between the output of the power supplies and ground (many locations including LI01 Chicane Quads, EP01 Septa and the LI30 individual QUADs with individual boosters).
 - F. SLAC Built / Rebuilt ACME Power Supplies: Use two 50 ohm, 100 watt wire-wound resistors in series.
 - G. PEP II ZFT Regulator/Controller Chassis: Uses a 50 ohm, 50 watt wire-wound resistor attached between the negative power supply buss and ground.
 - H. Blow Torch Quads: Use a 100 ohm, 50 watt wire-wound resistor per rack attached between the output of the mother power supply and ground.
 - I. The LI02 through LI04 Quads use a 100 ohm 100 watt wire-wound resistor attached between the negative buses of the power supplies.
 - J. Many systems do not monitor for ground current: Copley, multi-channel driver chassis, MCORs.

Types of Control Logic

1. EMHP Control and Interface Chassis: Analog reading is true but we had to attach labels indicating the meter scale was milliamps rather than microamps. We are replacing incandescent bulb meters with LED meters. There is a plan in place for the next downtime. Normal trip setting is 60 ma.
 2. SLC PS Reg/Cont Chassis (digital meter) and DC Power Supply C&I Chassis (no meter): Use a “Unity Gain” control logic PCB by which the indicated ground current shows 1volt per 10 ma of ground current. Normal trip setting 25-75 milliamps
 3. Klystron Focus Magnet (no meter) and Low Voltage Controller (digital meter) use a “200 Gain” control logic PCB by which the indicated ground current as follows:
 - a. Klystron Focus Magnet: 1V = 2.5A (2500 ma). Normal trip setting is 5 amps
 - b. LV Controller: 1V = .25A (250ma). Normal trip setting is 50-75 milliamps.
- Note: Many of these have been corrupted as far as proper gain and set-point from lack of system knowledge that I will correct this a.s.a.p or during the downtime.
4. PEP II ZFT Reg/Cont chassis uses a digital meter and a unity gain control logic PCB by which the indicated ground current shows 1volt per 20 ma. Normal trip setting is 10 milliamps.
 5. Blow Torch Quads uses a unity gain interlock card. Normal trip setting is 50 milliamps.

What is Acceptable Ground Current and Who Determined This?

1. Older SLC Magnet Systems: Less than 100 milliamps
2. Klystron Focus Magnet Systems: Less than 2 amps
3. Newer PEP II Magnet Systems: Less than 10 milliamps
4. Blow Torch Quads: Less than 20 milliamp

Types of Ground Current Fault

1. Dead Short: Linear increase in ground current with little or no voltage indicated (aluminum foil, worn insulation, shorted conductor, failed power supply).
2. Spike Trip: No ground current until a voltage level is reached. Then a sudden trip (twister, grabber, failed power supply).
3. Fluctuating ground current increasing as power supply is run-up to rated voltage and current (water leak, corrosion, dirt).

Diagnostic Equipment Available for Ground Current Troubleshooting

1. DVM:
 - A. Ohm-meter
 - B. Volt-meter
2. Hi-potter
3. Dummy Loads
 - A. AMWs Ice Cream Machine
 - B. AMEs Allan Freese Load
4. Power supply shorting strap.
5. Portable Power Supply.
6. AME Bitbus has SCP diagnostics available.

Responding to a Ground Current Trip

1. Attempt to reset the fault
 - A. If not re-settable:
 1. Analog Meter: Check the meter bulb for brightness, comparing it to others nearby.
 2. Mechanically agitate the meter and attempt to reset.
 3. Power cycle the controller chassis by removing and reinserting the chassis fuse and attempt to reset.
 4. Jumper J5-A and B and attempt to reset.
 5. Replace the meter bulb, control logic PCB or driver chassis as indicated by the troubleshooting results.
 - B. Successful reset: Switch system to "Local". Turn it on and run it up to determine whether there is a real fault and if so whether it is #1, #2 or #3 fault. Always note and document the trip setting, calculate the current trip point and the power supply voltage and current at which the

trip occurs. Run the power supply up to its highest operating current as designated by IMMO(2) on the Systems “Single Unit Display”.

Checking the Magnet String for a Ground

1. In the case of a dead short fault (#1), measure resistance between the power supply negative buss and ground with an ohm-meter. On an EMHP this can be done without dismantling it by measuring between TB3-8 (-V) and ground. If the measurement is less than the known value of the of the ground sensing resistor, there is a problem. Unhook the load and measure it and the power supply separately.
2. Hi-Pot the load disconnected from the power supply. SLAC ES&H Manual, Chapter 8: Electrical Safety, Section 4.2 and Maintenance Procedures and Policies for PCD Equipment #84 establish rules and guidelines for hi-potting to prevent personnel injury or damage to equipment. In general, I say that that a typical iron-core magnet or magnet string should hold off 1Kv of hi-pot. Special magnets such as septa or kickers should be handled differently with the assistance of area physicists and responsible engineers.
3. Know that hi-potting will not necessarily detect a “twister” or “grabber”.

Checking the Power Supply for a Ground

1. Do the ohm-meter check with the load disconnected.
2. Turn it on unloaded (max voltage, no current, I/V switch vs. no I/V switch).
3. Turn it on and run it up slowly with the output shorted (max current, no voltage)
4. Turn it on and run it up on a dummy load configured for the operating voltage and current.

Very Important Consideration

Even when a problem is detected in the load, during the time required to set access and do radiological surveys, maintenance staff should check the power supply (EMHP) as indicated above to the extent possible.

Solutions to a Ground Current Situation

1. Replace the defective control logic PCB
2. Replace the defective controller chassis
3. Replace the defective power supply
4. Find and resolve the ground on the magnet or magnet string
 - A Visually locate the fault.
 - B. Audibly locate the fault

Note: I developed the EMHP Test Stand to disable the ground current trip function in order to see it and hear it.
5. Raise the trip point if indicated: Level of authority = Maintenance Manager
 - A. Analog Meter
 - B. Control Logic PCB

6. Track down ground by using Pete Segura's portable power supply voltage drop scenario (document included) or float it and run it RASKed. EMHP Test Stand was designed to make this easy.
7. Float the system and continue operations: Level of authority: EOIC, AMG
8. Install Nulling Bridge: Level of authority: PD, Area Physicist.
9. Split the string using a second power supply: Level of Authority: Area Physicist.
10. If possible to continue operations, zero DAC and, if necessary, disable companion magnet. ACT>DES to green them until corrective maintenance can be performed. Steer around them to maintain an acceptable beam orbit.

What I am doing about this problem?

1. Presented this to Area Managers and some Operations, MFD and ESD staff
2. Taking their input back to my staff A.S.A.P.
3. Assigned my staff to review baseline data and updating stickers on controller chassis.
4. Assigned my staff to check that all Control Logic PCBs (237-212-01) are properly labeled.
5. Working with Dan Wright of MFD on procuring standard hi-potters and establishing specific hi-pot limits for specific systems.
6. Revisiting all controller chassis for proper set-point and gain application A.S.A.P. but most certainly during the downtime.
7. Replace all incandescent meters with LED meters.
8. Encourage maintenance staff, operations and area managers to consult me when there is a problem especially when there is a significant degree of confusion involved. I have made an effort to be present on the contact list. It is my job.

Additional Pertinent Documentation: Provided by Wayne Linebarger around the question of who is responsible for what in troubleshooting and repairing ground current problems.

1. "Standard Procedures for Labeling Magnet Terminals, Power Supply Terminals and Power Cables"
2. "Damping Ring Magnet Power Connection Specification"