Hipotronics
Model 815-15A
High Voltage, Variable DC Power Supply
revised September 11, 1997

This paper describes the power supplies purchased under SURA contract 97-C1541. The power supply delivers a variable output voltage and was designed to operate eight CEBAF-type klystrons at power levels from 2 kW to 8 kW CW for each tube.

Parameter	Value	Units
Output voltage range (nominal)	-7.5 to -15	kV DC
Output current (maximum)	15	Amps
Output ripple	0.1	% p-p
Number of outputs	8	each
Input voltage (main)	480	V AC, 3Ø
Input current (full load - see test data)	290	Amps
Input voltage (controls & auxiliary)	120	V AC, 1Ø
Input current (controls & auxiliary)	5 (typ)	Amps

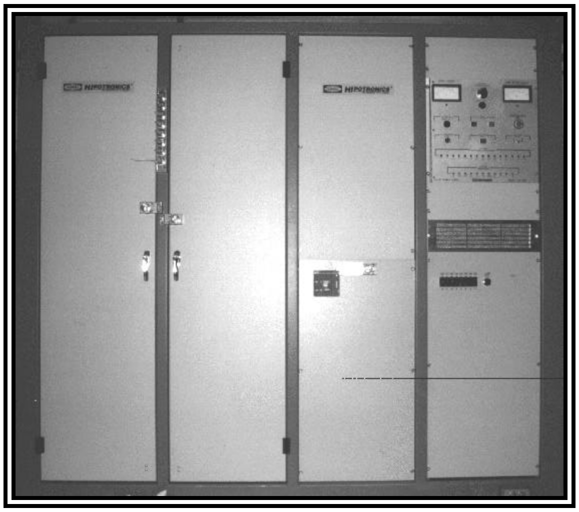
The power supply has the following major elements (note: the numbering in these lists does not refer to any following paragraphs or sections that follow).

Power Elements
1. main circuit breaker
2. contactor
3. SCR phase controller (for soft start only)
4. transformer, fixed (480:480)
5. transformer, variable (PVT) (0:480)
6. transformer, step-up
7. rectifier assembly
8. filter assembly (LC)
9. ignitron crowbar assembly
10. output isolating resistors, 50 ohm

Controls, Protection, and Instrumentation
1. PLC (programmable logic controller)
2. relay logic for safety functions
3. interlock switches
4. Kirk key interlock system
5. AC phase imbalance monitor(phase rotation sensitive)
6. AC current transformers (for over-current protection)
7. voltage comparator board for PVT control (regulation)
8. LEM type current transformers, DC current measuring(2)

9. DC over-current board (JLAB SCR board)
10. HV dividers, compensated, for voltage monitoring, ripple measurement (2)
11. buffer amplifiers for analog signals
12. front panel meters (2), indicators (n)
13. over-current sense and crowbar controls
14. fiber optic receivers & transmitters for crowbar status, remote trigger

Physical Construction and Component Locations



The power supply is housed in a single, welded, steel cabinet approximately 4 bays wide. The dimensions are 72" hi x 48" deep x 90" wide with a weight of around 8,000 pounds. Access to the interior is made via lockable doors and screw-secured panels.

- The high voltage transformer, rectifier assemblies, crowbar, shorting solenoid, grounding stick and grounding points, 120 V isolation and filtering units, high voltage dividers, and output resistors are all located behind the two front doors.

- Access to the 480 V circuit breaker, filter choke, HV capacitors, and phase imbalance monitor is achieved by removing panels from the third bay.

- The PLC, output relays, buffer amplifiers, PVT (Peschel Variable Transformer) voltage regulator, DC over-current board, IO interface connections, low voltage power supplies, and PVT power supply are reached by removing two screws and hinging the front control panel outward.
- 120 V circuit breakers, the main HV capacitors and DC current sensors (LEMs) plus several resistors are located behind the panel at the bottom of the fourth rack bay (the right most bay).

Removing the two large rear panels provides access to the HV step-up transformer, the PVT, 480:480 transformer, the contactor, and the SCR controller assembly located on the right wall. Fuses for the SCR controller are located near the top of the assembly.

These are indicator fuses that also activate a switch and turn off the SCR controller should any fuse fail.

The PVT is probably the item most likely to require attention and access through the rear of the cabinet. Being mechanical by design, the brushes will have to be replaced after a number of years operation. While the brushes are metal and should last a long time, ultimate brush life will be highly dependent on the number of times the transformer is adjusted, either manually or automatically.

Power Systems.

The power supply requires both 120 VAC, 1 phase and 480 VAC, 3 phase.

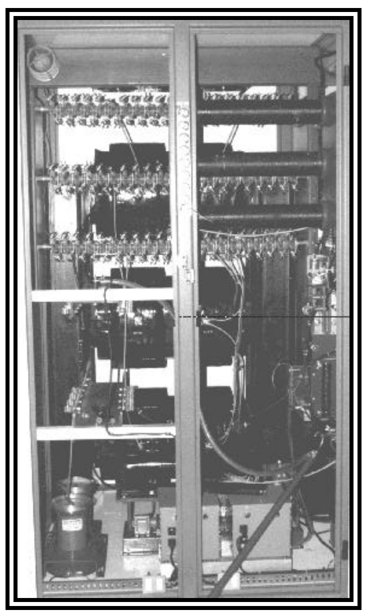
120 V is supplied to two separate circuits internally, though only a single external connection to a 120 VAC P2 breaker is used. One circuit is used for internal lighting and convenience outlets (auxiliary power), while the second is used for everything else (control power). Two isolation transformers with line filtering and transient suppression provide conditioned power. One isolation unit powers the fans only, while the other powers all remaining circuitry (low voltage power supplies, PLC, contactors, crowbar, SCR fans, etc. Circuit breaker CB2 is the control power breaker, while CB9 is the auxiliary power breaker. When working on the 120 V, the power feed must be locked and tagged in accordance with JLAB LOTO policies.

480 V enters the cabinet through the top and is routed to the main circuit breaker. An electronic circuit breaker, it may be adjusted to suit the specific needs of the customer. Trip current, curve, and delays may all be programmed. Maximum design current for the power supply is 320 A per phase. The circuit breaker is adjusted for 90%, or 360 A. In addition to being tripped by an overload condition, the breaker is also equipped with a shunt trip device designed to trip the breaker on command. The shunt trip is activated when the emergency off push-button is pressed. This insures that 480 VAC is switched off under certain emergency conditions. When working on the 480 V circuits or inside the main power supply compartment, the power feed must be locked and tagged in accordance with JLAB LOTO policies.

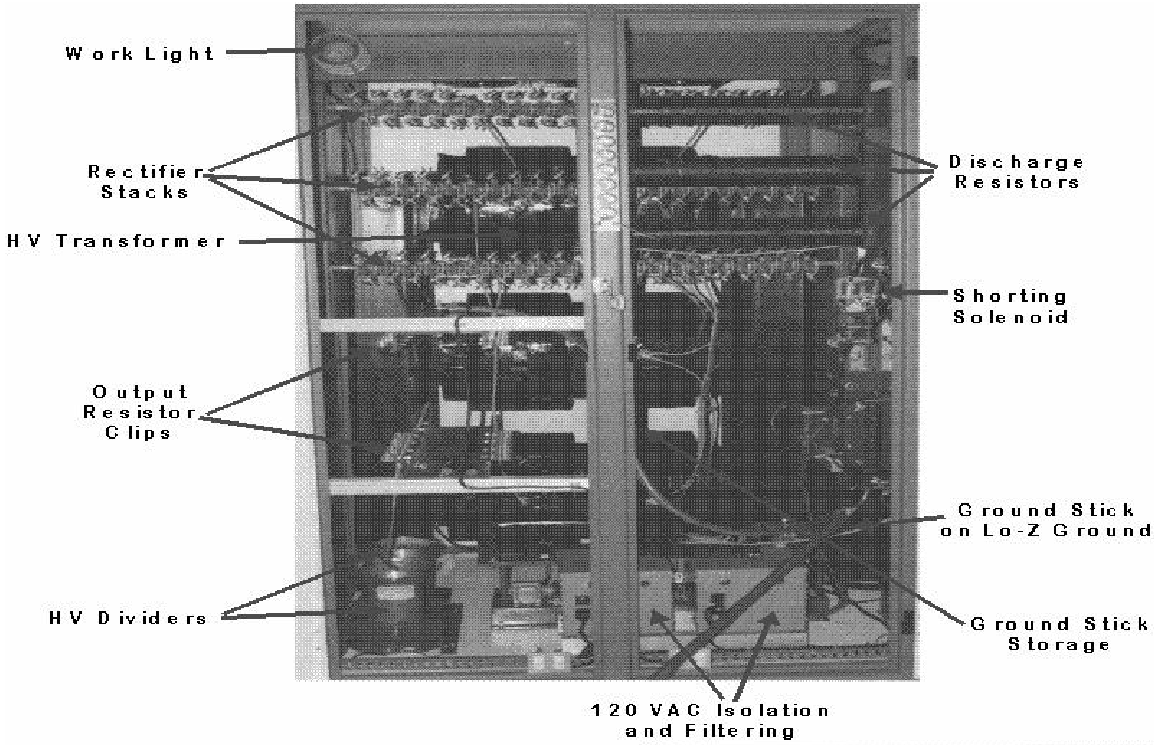
The output of the main breaker feeds a contactor which provides positive disconnect when the power supply is turned off. The contactor feeds an SCR controller, which is used for soft start and quick turn off only. The SCR unit is not used for phase control to vary the power supply output voltage. When the power supply is first turned on, the voltage applied to the transformers is automatically ramped from zero to fully on. This serves to limit inrush current during turn-on. There a 3 primary adjustments on the controller, though under normal circumstances, no adjustments should be required. The SCR assembly has 3 indicator type fuses, located near the top of the heat sink assembly. As a note, the SCR assembly is purchased, rather than built by Hipotronics.

An AC phase imbalance monitor monitors the 3 phase AC, and is connected immediately after the circuit breaker. The input to the monitor is fused, with fuses located adjacent to the unit. Adjustments for minimum and maximum line voltage and delay time until trip are provided. Since the unit is power by the line being monitored, it requires no additional power. The output of this device is an isolated relay contact which is applied to one of the PLC inputs and helps to determine whether the power supply can be energized. Adjustments to the phase imbalance monitor are accessed by removing the small rack panel immediately above the 480 VAC circuit breaker. When making any adjustments to the monitor, remember to use caution due to the exposed 480 V behind this panel.

Two sets of current transformers are included in this system (three counting the CTs in the SCR assembly) . Each set of three (one for each phase) connects to 3 separate circuit breakers on the front panel. High current, as might result from a shorted rectifier, will cause one or more breakers to trip. Auxiliary contacts on the breaker are part of the machine protection circuitry. When one of these breakers trips, the power supply will be shut down and the fault annunciated. One set follows the SCR controller, while a second set follows the PVT (variable transformer). This assures that a load fault on the PVT load side, or the PVT itself causing a load fault, will trip the system. A third set of three current transformers is part of the SCR controller and serves to shut down the controller in the event of excessive SCR current.



The main power conversion chain provides for the output voltage adjustable between -7.5 kV and -15 kV. This adjustment is made by a variable transformer of Hiptronics design. The unit, a Peschel variable Transformer (PVT) works in conjunction with a 480:480 volt transformer, adding up to 480 VAC to the 480 from this transformer. The primary of the high voltage step-up transformer sees a voltage between 480 and 960 VAC. The PVT is motor-driven, has adjustable mechanical stops to limit output voltage, but is primarily controlled by a feedback circuit that monitors the actual output voltage of the power supply. The output voltage may be set via a front panel knob, or an external 0-10 VDC input signal. A selector switch on the front panel determines which voltage reference will be used. A second switch (Zero bypass) determines whether the PVT will ramp to zero before the power supply can be turned on, or remain at it’s last setting.



HV Compartment
Hipotronics 815-15A
Power Supply

The high voltage transformer is a three phase transformer with dual primary windings and dual secondary windings. The primary windings are both delta wound, while one of the secondaries is delta, and the other, wye. With full wave rectification, this delta-wye configuration provides reduced ripple through 12 pulse conversion. The ripple frequency of 720 Hz is 12X the line frequency of 60 Hz. The resultant rectified DC is coupled to the output capacitor bank through a 1 henry inductor. While very effective at reducing 720 Hz, low frequencies are attenuated lesser amounts. Inaccuracies in the transformer windings, coupled capacitance between windings and ground, and incoming line phase imbalances can result in ripple frequencies other than 720 Hz, especially 120 and 240 Hz. The predominant frequency observed during testing was 120 Hz, though even this was attenuated enough to meet specs.

The filtered DC is next fed to eight, 50 ohm resistors for distribution to the 8 klystrons attached in the companion HPA. The power supply is equipped with a mercury ignitron electronic crowbar. During an over-current condition (current typically greater than 18 amps), the voltage across a series-connected sense resistor in the output leg causes the ignitron to be triggered into conduction. This puts a near short on the output of the power supply, diverting the fault current from the load. At the same time, a shut down procedure is initiated and the power supply is turned off by the PLC.

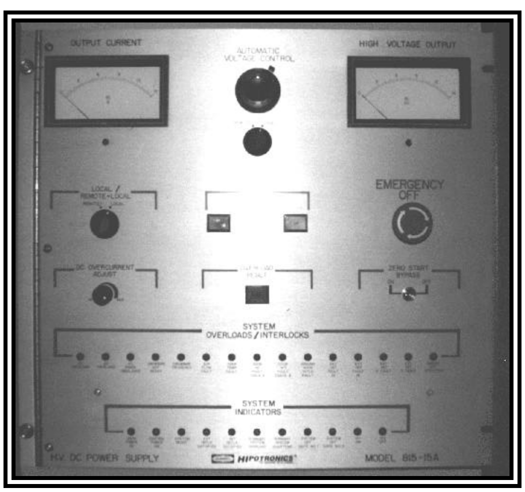
The crowbar assembly is built on red fiberglass channel located on the floor of the power supply, directly in front of the high voltage transformer. Because the power supply is negative output, the crowbar trigger circuitry is connected to the high voltage output. External interfaces are electrically isolated from high voltage. The crowbar chassis contains a high voltage isolation transformer that powers the circuitry. Status signals are conveyed over insulated fiber optic cables through HP receivers and transmitters. The trigger electronics and the ignitron are both enclosed in a clear acrylic case to prevent accidental contact. The ignitron anode is also heated by 2 power resistors located near the anode of the tube inside the protective plastic case. The heater resistors are powered by 120 VAC from the same isolated power source that powers the crowbar chassis. If power to the crowbar is on, there will be 120 VAC on these resistors, so use caution. The crowbar has one adjustment, for trip level.

DC output voltage is sampled by two identical compensated divider networks. The 50 ohm BNC outputs provide signals for both local and remote metering. One divider output also connects to an isolated BNC connector that can be used to examine output ripple. A buffer amplifier allows the remote output to be scaled so that 10 volts = 15 kV.

DC output current is monitored by non-contact LEM devices (DC current transformers) in the return leg of the output. The current being monitored is carried by the green wire, 6 turns of which are wound through the open center of the LEM. Six turns are used to develop greater output current (voltage) since this is a 100A full scale device. One output is used drives the local display meter, while the second is used for remote monitoring. The output of this sensor is adjusted for 10 V output = 15 Amps.

Controls

The power supply is operable either remotely or locally. Local, front panel controls allow the supply to be turned on and off, latched faults to be cleared, and output voltage to be adjusted. These same functions are also controllable remotely. All digital (on/off) operating controls are controlled by a Programmable Logic Controller, or PLC. Analog signals, like the setpoint voltage and output voltage, are not monitored by the PLC.



The PLC is a PLCDirect series 340 PLC. While it provides backup for safety functions, personnel related safety functions are first handled by redundant mechanical switches and relay logic. The PLC is the gateway through which all on/off and fault annunciation is controlled. Optically isolated inputs allow the remote 24 VDC inputs to signal the PLC, while relay contacts output by the PLC provide status indication of operating states and fault conditions. The PLC also has outputs that drive local status LEDs and relays.

Connections to the PLC and other I/O connections are behind a hinged front panel at the right side of the power supply. When open, access is available to the PLC, control relays, and the remote interface connections.

The PVT is equipped with a voltage regulator card designed to maintain the output voltage constant within a preset window. Local or remote voltage setting is selected by a switch on the front panel. Also, whether the PVT will remain at the set-point or return to minimum output before the supply can be turned on is determined by the setting of the Zero Bypass switch on the front panel. With Zero bypass ON, the PVT will remain at it's last setting and will only move as required by the voltage regulator board once the power supply is turned on (if this option has been programmed into the PLC). The alternate function of this switch is to enable or disable the regulator board entirely.

Safety interlocks include the door switches, an emergency off switch, and external permissives (from both the PSS and HPA). The power supply can not be energized if these interlock chains are not satisfied. The PLC also monitors the interlocks, and will force the power supply off, though the primary safety controls remain in hardware. Power for local interlocks is provided by a 24 VDC power supply located in the PLC compartment.

Safety Elements

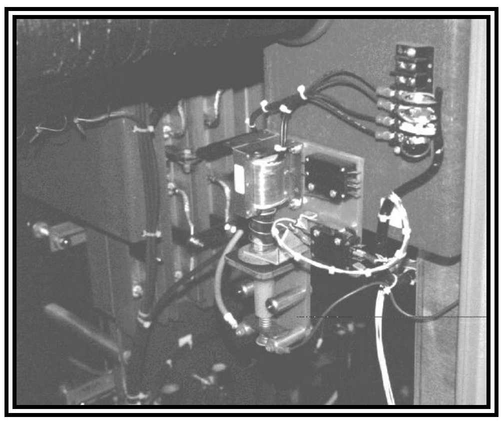
Before beginning work on this power supply, the operators should read and understand the SOP approved for this equipment. In it are contained information on the hazards presented, their mitigation, and required safety procedures.

Several different methods of personnel protection are incorporated in the design of this power supply. Both mechanical and electrical devices are used. The 480 V circuit breaker may be locked in the off position using standard hasps and padlocks. The two front doors are lockable, both by a standard rack key, and by a Kirk key system. Each door has a unique key, as does the main 480 V circuit breaker. A key transfer block houses all keys, and locks them in if the key from the circuit breaker is not inserted in this block. To open the doors, the circuit breaker must first be tuned off and the Kirk key rotated to lock the breaker. The key is removed, inserted in the transfer block and rotated. This releases the other keys, which may now be removed. With the appropriate key, any of the doors may now be unlocked. The locks are such that the key can not be removed if the door is not closed and locked. And, the master key for the circuit breaker cannot be removed until all door keys are back in the transfer block. This prevents operating the power supply with any door open. Five additional keys allow access to the five HPA doors.

Other access points to the power supply include front, rear, and side panels. In accordance with Jefferson Lab safety policies, each panel has a minimum of 4 screws (and typically 6) securing it.

Each of the doors is equipped with dual interlock switches. The contacts from these switches go to PLC inputs (for status annunciation) and hard-wired relay logic. In addition to local door interlocks, the safety chains also have inputs for external interlocks. These include PSS and HPA. When connected, opening any of these interlocks will prevent the power supply from coming on, or if already on, immediately shut it off. Local LEDs on the control panel indicate which door is ajar.

The capacitors in the filter network are discharged through several paths. The capacitors have a fixed bleeder resistor connected across them at all times. When the power supply is turned off for any reason, a shorting solenoid, located inside the right front door, drops, discharging the capacitors through a bank of high power resistors. These resistors are robust enough to trip the circuit breaker should the solenoid close with AC power still applied.



The final discharge path is through the manual grounding stick, also inside the right, front door. After verifying that the automatic shorting solenoid has dropped, the grounding stick should be removed and touched to the Hi- ground point. This allows the capacitors to be discharged through a 450 resistor bank. The grounding stick should next be touched against, and finally hung on, the Lo-Z grounding point.. One this has been accomplished, the capacitor bank will remain in a discharged state. Remember! High voltage will be off and the capacitors discharged, but there may be live 120 V AC still present in the cabinet. Use caution at all times.

Maintenance Items

Minimal maintenance should be required for this power supply. Period inspection and routine changes of the air filter, replacement of burned out push-button indicator lights, plus replacement of the PVT brushes after many years use, should be the only “routine” maintenance items. As with any high voltage equipment, high voltage components should be kept clean and dry to prevent tracking and arcing.

The commutator strip for the PVT brushes should be kept clean and free from oils. If the unit makes substantial noise when it's in motion, the commutator strip should be cleaned with isopropyl alcohol and then wiped with a thin coat of silicone. Be certain to observe all required LOTO requirements when performing any maintenance inside the power supply.

Additional Information & Subsystems

Crowbar

The crowbar is a Hipotronics design, using an EEV ignitron as the shunt device. The cathode of the ignitron is connected to the HV output of the power supply and the filter capacitor. A sense voltage applied to the crowbar trigger circuitry is developed across resistor R34. When the ignitron is triggered, it conducts, and shunts the output of the power supply to ground. The ignitron is equipped with a holding anode to ensure that the tube will remain in conduction, even if the discharge current drops below the holding current or passes through zero due to ringing. Firing of the ignitron also initiates a turn-off sequence for the power supply, starting with disabling the SCRs, and ending when the PLC opens the main contactor.

The crowbar assembly is mounted on a red fiberglass channel, bolted to the floor of the power supply immediately in front of the high voltage transformer. The chassis has a large high voltage isolation transformer plus other transformers and circuitry. The isolation transformer is required since the remaining circuitry is referenced to the high voltage output. The transformer powers a 24 volt power supply (used for one of the fiber optic links), and an additional transformer that develops the 420 volt ignitor power supply and the 140 volt holding anode power supply. One additional transformer delivers the pulse to the ignitor. Two power resistors are used to heat the anode assembly. Note that these resistors are power by 120 VAC. The ignitron and circuit boards are normally covered by a clear plastic cover to prevent accidental contact with the DC voltages contained on them.

The trigger circuit responds to the voltage developed across R34. When it exceeds the trigger voltage (as set by R18), triac Q2 fires, dumping C4 into the gate of SCR, which fires and dumps C5/C6 into the pulse transformer. The ignitron conducts, at which time current will automatically be drawn by the holding anode. Remote status is provide through optical isolation using fiber optic cables. Opto-isolator 1 monitors the holding anode supply voltage, opto 2 indicates the trigger supply is charged, opto 3 indicates the crowbar fired, and opto 4 is an external trigger input. All fiber optic cables terminate at the crowbar chassis on one end, and an opto-isolator board in the PLC compartment on the other. As built, the external input is considerably slower than the primary trigger input. The external input is optically isolated, but must release a relay whose contact in turn triggers the crowbar. If greater speed is required, the circuit can be redesigned to eliminate the relay, allowing the opto receiver to driver a transistor and the triac directly.

Once triggered, the PLC will latch the fault condition until it is manually reset. The power supply cannot be turned on until the fault is cleared and the circuitry is again charged and ready. The crowbar itself is thus self resetting.

A self-test of the circuit, including the ignitron, can be done with the power supply either on or off**. Note: executing the test will shut the power supply off when the crowbar fires, so *don't* do it if the supply is supposed to be up and running!** To manually fire the crowbar, press and hold the *Lamp Test* push-button for 5 seconds. All front panel lamps should illuminate. After 5 seconds, all lamps not normally lit should extinguish. If the test resulted in proper crowbar operation, the *Crowbar Fired* and *Crowbar Not Ready* indicators should remain lit. These may be reset in a few seconds after the crowbar circuitry recycles.

PLC

The PLC is a PLCDirect by Koyo, model 340 with main and expansion chassis. The expansion chassis houses only one card and a power supply at present. Four types of IO modules are used in the system: opto-isolated input (both 8 and 16 points), transistor output (16 points), and relay output (16 points). Inputs modules monitor switches and remote control functions. Output modules light the front panel LEDs, control external relays, and provide status monitoring for remote control. The PLC is not equipped with any analog modules, so no analog functions are controlled or monitored by the PLC. The PLC contacts may be monitored, and the unit programmed, using an IBM compatible PC.

Sequencing of the power supply, monitoring and reporting status, and fault protection the primary functions of the PLC. Safety contacts are monitored, but used only for redundant control. Personnel safety functions are handled in relay logic, so the PLC acts as a backup only.

As the PLC code may be modified if required, consult the latest printout for details on its operation. Changes should be noted, and comments used liberally throughout the listing to make the logic easier to understand for future users.

Power Line Isolation and Auxiliary Power Supplies

The 815-15A has two isolation transformers used to power 120 V circuits. One is used only for the blowers, while the other provides power for everything else. The 120 is supplied by a separate feed (rather than stepped down from the 480 V input) to allow the controls circuitry to be worked on with 480 V locked out. These are the two blue boxes on the floor of the power supply behind the front doors. Each contains an isolation transformer plus power line filtering elements. The secondary of this transformer has 3 taps. Assuming a nominal 115 VAC input, the taps are 105, 115, and 125 VAC. One side of the isolated secondary is grounded to the frame. The isolation transformers receive power through circuit breaker CB2, located on the right most rack bay, but are individually fused for protection.

A number of systems require 120 VAC, including the PLC, main contactor, SCR controller fans, shorting solenoid, blowers, PVT, PVT regulator board, crowbar, and two auxiliary low voltage power supplies. The SCR controller itself derives 120 VAC for the electronics from a step-down transformer. A +24 V supply in provided for LEDs and controls use, while a ±15V supply powers the buffer amplifier card and LEM current sensors. These two power supplies are located in the PLC compartment, along with the PVT regulator, buffer amplifiers (for voltage metering), DC over-current board, PVT power supply, and various control relays. Note that these two power supplies, plus the PVT supply, have fuses on the power supply assemblies.

Instrumentation

The 815-15A has analog monitoring of both DC output voltage and current. Voltage is measured by two compensated high voltage divider assemblies (left side of main cabinet, on the floor) with BNC output connectors. One divider has a 1000:1 ratio and is connected to a front panel-mounted BNC jack. The second divider is 200:1 and feeds the front panel meter directly and connects to the inputs (2) of a buffer amplifier board. The amplifier provides scaling adjustment for the remote 0-10 V signal and also supplies a measured output of the power supply to the PVT regulator board. Pots on board allow offset adjust, and span calibration. Accurate adjustments necessary to maintain a proper regulated output voltage and measured voltage signal for remote monitoring.

Current monitoring is via dual LEM DC current transformers. These 3-terminal devices are located near the right end of the power supply. Each has two adjustment pots, one for zero adjust, and one for span adjust. The LEMs are powered by the ±15 V power supply in the PLC compartment. Both LEMs are rated at 100A full scale. Since the power supply only outputs 15A, 6 turns of wire are passed through the core to give a measurement field equivalent to 90A. This provides a higher output from the LEM. The wire passing through the core of the LEM connects the positive output of the supply to ground, so the wire is at ground potential. One LEM drives a front panel meter while the other connects to the DC overload board and provides a 0-10 V signal for remote monitoring. The zero pot is adjusted to provide zero output with no measured current while the span pots are adjusted to give the correct reading for the current being measured. When properly adjusted, the LEM output voltage should be 10 V for 100 Amps.

The LEMs may be calibrated by passing a known current through the wire in the measurement opening, or by inserting a secondary ammeter in series with the sense wire to ground. Since high voltage would be present if the power supply itself is used to calibrate these sensors, it is recommended that an external power supply be used instead.

Adjust the zero (offset) to minimum with no current through the core, then apply a know current and adjust the span until the correct current is read. This adjustment should be made with an accurate voltmeter connected to the LEM output. Following the LEM adjustment, the front panel meter can be calibrated using its calibration pot on the metering board.

Measuring High Voltage

Extreme care must be exercised when making high voltage measurements! Lethal voltages may be present, even with the power supply turned off!

The power supply has a BNC connector on the front panel, internally connected to a 1000:1 compensated divider. While it was intended for monitoring output ripple, it is also accurate for monitoring the DC output level. Care must be when using this device to measure ripple. The divider is located immediately in front of the main high voltage transformer, and spurious signals and noise may be introduced into the measurement. In addition, use of a grounded scope may also induce undesired ground loop currents, resulting in erroneous readings. When accurate ripple readings are required, an appropriate high voltage probe should be connected to the high voltage output and system ground, and an isolated scope input should be used if possible.

There is no adjustment to calibrate the 1000:1 divider to be exactly 1000:1..

SCR Controller

The SCR controller, HDR Power Systems PF3-480-500-EG-OC contains all the circuitry needed for controlling the incoming AC power. . The controller provides for soft start (in lieu of using a step start contactor arrangement), and turn-off faster than can be accomplished using the contactor. While the contactor could be used to adjust output voltage, the additional noise and ripple produced by driving the transformer with a chopped sinusoidal input would require greater DC filtering with subsequent higher energy storage. For this reason, the output voltage of the power supply is controlled by a variable transformer system.

Three adjustments can be made to the controller via 10 turn pots on the front of the controller enclosure: the current trip point, zero, and span. Zero and Span are adjusted to provide full conduction for the SCRs with whatever range of command signal is applied to it. Typically this would be either 4-22 mA or 0-10 VDC. For this application, no connections are made to the command signal input, and only an enable/disable signal is used to activate the controller.

The preferred method of adjustment of Zero and Span is as follows:

1. Set both Span and Zero pots fully CCW to begin with.
2. While monitoring the voltage across the SCR, turn the zero pot CW until the voltage drops to a minimum. Initially, the voltage will be full line-line voltage, then will start to fall and continue decreasing as the pot is turned CW until a minimum (not zero) is reached. From experience, the minimum voltage is typically be between 1.25 and 1.5 VAC.

The result of this adjustment procedure will assure that full conduction is achieved, and even more important, that overshoot during turn-on is eliminated. Turning the supply on too quickly (soft start is set too fast) will result in excessive output voltage. This results from high inrush current through L1 charging the main cap bank. When the cap bank is fully charged, the change in di/dt results in an output voltage spike. The degree of overshoot is somewhat dependent on the load, as is the duration of the overvoltage condition.

The controller is also equipped with an overcurrent trip. A switch on the circuit board of the controller selects whether reset from a fault condition is automatic or manual. When the unit trips and the switch is set to manual (auto reset off), the power supply will remain off until the push-button is pressed (or the power is cycled?). If this is true, a fault will, in fact, reset automatically as the power is cycled.

PVT and Regulator

The PVT sits on top of a large transformer near the back of the cabinet. This motor driven variable transformer is equipped with limit switches that may be set to limit minimum or maximum output voltage. The motor itself is a DC unit, so the polarity of the power applied determines its direction. The power supply for the motor consists of a transformer, rectifier block, and various relays for control. A small variable transformer is used to adjust the rate of rise of the transformer (motor speed) during regulation. A separate transformer tap supplies higher voltage to run the PVT down to zero faster when the power supply is turned

The regulator card is located inside the PLC compartment. It is designed to maintain output voltage within a preset dead-end. This dead-end is adjustable, but should not be made too tight since the result would be constant hunting of the PVT as it tries to maintain a precise voltage. The goal should be to maintain output reasonably constant. The board is a universal Hipotronics unit and may be used in positive or negative polarity supplies by changing the configuration of the board.

Its circuitry consists of a power supply, comparators and amplifiers, and output relays. In operation, a reference signal (either from the front panel 10 turn pot or an external 0 to +10 V reference) is compared with the output voltage (negative) of the power supply. If the error signal exceeds the deadband setting (set by R9 on the regulator board), the PVT motor will run in the appropriate direction to either increase or decrease the PVT output voltage. LEDs on the board show the present status. For this power supply, a yellow LED indicates the error signal. The brighter it is, the greater the error. Green indicates the PVT is being commanded to RAISE, while red signifies LOWER. If the power supply has been turned off, and the zero bypass has not been turn on, the PVT will lower itself to zero.

When properly adjusted, the local voltage control knob and remote voltage input should closely agree with actual output voltage. Because the regulator has a deadband, and because there are discrete steps on the PVT, actual voltage will not necessarily always exactly match the programmed voltage. If the error is greater than can be tolerated, the regulator circuit should be adjusted.

To adjust the local pot and remote programming input for proper scaling, perform the following steps:

1. Set the voltage selector switch to REMOTE.
2. Apply an accurate 8.00 volts to the remote input. The use of a Datel voltage source is ideal.
3. With the power supply turned on, adjust R3 (15 turn pot) on the buffer card until the power supply output voltage is 12.0 kV.
4. Next, set the front panel pot to 8.00 (it's a 15 turn indicator, but only turns 10 turns).
5. Move the voltage control selector switch to REMOTE.
6. The power supply output should remain at or close to 12.0 kV.
7. If the PVT runs and the voltage changes by more than is desired, adjust R2 on the regulator board until the power supply output again reads 12.0 kV.
8. At this point, switching between LOCAL and REMOTE should cause little or no change in output voltage.

The PVT itself is a three phase, variable transformer. Unlike a rotary variable transformer, this design puts all three phases in a more conventional 3 phase transformer configuration. The transformer windings are vertical, and the moving brush assembly is driven by a DC gearmotor through sprockets and chain drive. Each phase of the transformer has two pickoff points for separate brush assemblies. These are designed to connect to odd and even turns. The parallel brush assemblies are connected through high current diodes, designed to provide direct shorting of turns as the brush traverses from one turn to the next. Each brush assembly contains 3 metal brushes, so a total of 18 brushes are used in the full transformer.

Lubrication of the brushes may be required to keep audible noise to a minimum. Use of a lubricant recommended by Hipotronics is suggested.

Low Voltage Power Supplies

The power supplies are standard, off-the-shelf, linear type power supplies. ±15VDC is supplied for LEM and buffer board, while +24VDC is provided for the DC O/L board and control functions. Power supplies are individually fused, powered from CB2, and mounted inside the PLC compartment behind a sheet metal cover to prevent contact with the exposed 120 V that powers them.

Control Relays

Numerous control relays are used in this power supply. With the exception of K1, the 480 V contactor, all are the same 24 VDC, 4PDT, plug-in relays. K2-19 are mounted on the left inside the PLC enclosure, while K20-22 and spares are on the right. Sockets have diodes across the coil connections to prevent spiking in the power supply and arcing across contacts used to switch the relays.

Several relays are used for contact multiplication. In other words, one contact activates the coil, while the 4 relay contact pairs provide additional contacts for use in other circuits.

This is required for safety interlocks (PSS and HPA) so that the one contact supplied can be used in relay logic for safety circuits, and also monitored by the PLC for status indication.

Fiber Optics

Fiber optic cables are used to monitor and control crowbar functions. Three links send status for crowbar fired, crowbar ready (+140 V), and crowbar ready (+420 V) to the receiver board and ultimately the PLC, while one addition fiber runs to the crowbar to initiate a crowbar firing. This is the remote crowbar trigger input. The transmitters, receiver and fiber are made by HP. The fiber is a large diameter, plastic type that is easily terminated in the field if repairs are required. LEDs on the fiber optic transceiver board (located inside the PLC compartment), show the status of the various functions. The two lower LEDs should be off if the two DC supplies are properly charged on the crowbar. The upper red LED will blink off momentarily if the crowbar fires. Since the PLC monitors all three signals, all it takes is one missing signal to shut the power supply off. The supply may not be turned off if the crowbar is “not ready”. The importance of the “crowbar fired” indicator lies in the fact that this signal will directly turn off the SCR controller. The “not ready” signals will do the same, but must first be processed by the PLC and are therefore somewhat slower to respond.

Schematics & Drawings

Schematics, drawings, and parts lists have been provided by the manufacturer, Hipotronics. Prints for the major elements include the power supply, regulator board, buffer amplifier, and PLC IO assignments. In most cases, wire numbers and IO terminal numbers have been included to simplifying diagnosing problems. A copy of the PLC code is also provided, though is subject to modification as required so some differences may be found.