Intermediate Power Supplies

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Brief Summary
This specification covers the minimum requirements for rack-mounted power supplies with output power ratings from 2.5 kW to 22.5 kW. The power supplies provide controlled, precise, and stable DC current to electromagnets in the Stanford Linear Accelerator Center’s (SLAC) Linac Coherent Light Source free electron laser.

Important Note
The fact that a manufacturer supplied similar power supplies in the past is not a basis for disregarding the requirements of this revised specification. Seller is required to satisfy all requirements unless Purchaser allows a deviation in writing.
## Change History Log

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1.0 SCOPE
1.1 This specification covers the minimum requirements for rack-mounted power supplies with output power ratings from 2.5 kW to 22.5 kW. The power supplies provide controlled, precise, and stable DC current to electromagnets in the Stanford Synchrotron Radiation Laboratory’s Linac Coherent Light Source free electron laser located at the Stanford Linear Accelerator Center (SLAC). Hereinafter both SSRL and SLAC are referred to as Purchaser.
1.2 Design, manufacture, install and integrate Purchaser-furnished components, label, perform quality assurance, test, package, and deliver the power supplies in accordance with the requirements of this Specification and the Purchase Order.
1.3 Power Supply voltages, currents, and power ratings shall be as specified in the Purchase Order.

2.0 AMBIENT CONDITIONS
2.1 Prevailing ambient conditions at Purchaser’s site located in Stanford, California are:
2.1.1 Location …………… Indoors
2.1.2 Temperature ………. 40 °F (4 °C) minimum to 113 °F (45 °C)
2.1.3 Elevation ………….. 900 ft above sea level
2.1.4 Humidity …………… 10% to 100% relative humidity with a 50 °F dew point

3.0 APPLICABLE DOCUMENTS
3.1 The latest issues of the documents listed in Table 1 apply. In the event of a conflict between the requirements of this Specification and any of the listed documents, this Specification governs.
4.0 REQUIREMENTS

4.1 Provide an adjustable output, constant-voltage or constant current Power Supply complete with internal control loops. Purchaser, however, will use the Power Supply as an ultra-stable constant-current source feeding an inductive magnet load. Achieve the constant-current operation by closing an external control loop consisting of a Danfysik Zero-Flux Current Transductor and a Ethernet controller chassis that contains the external current regulation circuitry. A redundant Zero-Flux Current Transductor provides current monitoring verification. Purchaser will provide the Ethernet Chassis and two Zero-Flux Transductors. Refer also to Figures 1 through 10.

4.2 This Section describes the required performance of the Power Supply as a controlled voltage source or current source, with Purchaser’s external control loop in the open state. The Power Supply output voltage and current ratings shall be as listed in the Purchase Order and shall apply at the maximum specified ambient temperature.

4.3 Operating life shall be $\geq 20$ years (174,000 hours) at continuous full-load duty with an MTBF $\geq 60,000$ hours, exclusive of electrolytic filter capacitors and fans, when calculated by the parts stress method of MIL-HDBK-217F.
4.4 Power Supplies rated ≤ 5 kW shall operate with Purchaser’s input 208 V ± 5%, 60 Hz, 3 φ, plus a ground wire. A neutral wire will be provided, if needed. If a neutral is needed, Seller shall provide line to neutral snubber circuits for input circuit breaker and rectifier protection. Phase voltage imbalance will be ≤ ± 2%.

4.5 Power Supplies rated > 5 kW shall operate with Purchaser’s input 480 V ± 5%, 60 Hz, 3 φ, plus a ground wire. A neutral wire is provided, if needed. If a neutral is needed, Seller shall provide line to neutral snubber circuits for input circuit breaker and rectifier protection. Phase voltage imbalance will be ≤ ± 2%.

4.6 Provide a front-panel mounted circuit breaker with an interrupting capacity ≥ 5,000A, RMS, symmetrical, to protect Power Supply components.

4.7 Generate operating and control power internally within the Power Supply.

4.8 Remove all power when an internal, appropriately rated, remotely controllable, electromechanical contactor opens. Provide an auxiliary, dry, normally closed, contact as part of the power supply remote turn on- turn off contactor. This contact will interface with Purchaser’s Machine Protection System (MPS). The contact, when closed, indicates that the power supply is capable of delivering an output. On the other hand, an open contact indicates that the power supply is capable of delivering an output to the load. The contacts connect to Pins 6 and 19 of connector J2. Refer also to Figures 1, 4 and 6 below.

4.9 Inrush current shall be ≤ 100% of full line current for all conditions of power application or switching start-up.

4.10 Input power factor shall be ≥ 0.9 when operating at rated output power.

4.11 The Power Supply shall not be damaged and shall turn off during the loss of any one phase or when the input line voltage deviates more than -30% to +15% from the nominal value. When restoring normal three-phase power, the Power Supply shall not automatically turn back on. A controlled turn on command shall be required to restore Power Supply operation.

4.12 Power Supplies shall be ≥ 85 % efficient at rated output power.

4.13 The Power Supply shall regulate in the constant voltage or current mode. The choice of constant voltage or constant current mode shall be made via a jumper in the P2 dummy plug as illustrated in Figure 4. The absence of the jumper shall set the constant current mode.

4.14 The Power Supply output voltage or current shall be remotely adjustable from 0 % to 100 % of full rated output voltage or current by Purchaser’s 0 V to + 5 V input analog signal.

4.15 Output polarity shall be as shown in Figures 10. The output terminals shall be isolated from the enclosure and ground, except for any EMI suppression circuits and the ground current resistor specified later in this specification.

4.16 Unless specifically specified otherwise, base the performance and test criteria given in this Specification on operation into a resistive load. However, the actual load is resistive or electromagnets with inductances ranging from 0.05 H to 1.0 H and with L/R time constants between 0.1 and 1.0 seconds. The Power Supply output voltage shall not exhibit any type of instability or oscillatory behavior throughout the voltage and current adjustment ranges specified when operated into a purely resistive load or Purchaser’s inductive loads.
4.17 The Power Supply shall be capable of continuous operation at its rated maximum output power in all specified environmental conditions when mounted in a ventilated rack. Seller shall provide information for any de-rating at higher temperatures. The Power Supply shall operate at any point defined on a V-I diagram within the voltage and current adjustment ranges specified in this Specification.

4.18 Output voltage stability shall be $\leq 200$ ppm/$^\circ$C of rated output voltage over the ambient temperature range specified in Paragraph 2.1. This requirement is applicable over an output voltage or current range of 10 % to 100 % of rated output.

4.19 Output voltage regulation shall be $\leq 500$ ppm (0.05%) of full rated output under the following conditions:

4.19.1. $\pm 5\%$ input AC supply voltage change

4.19.2 $\pm 5\%$ load resistance change

4.19.3 This requirement is applicable over an output voltage or current range of 10 % to 100 % of rated output.

4.20 The Power Supply voltage or current loop shall achieve above-specified regulation within $500 \mu$s under any of the following conditions:

4.20.1 $\pm 5\%$ step supply voltage change

4.20.2 $\pm 5\%$ step programming voltage change

4.20.3 $\pm 5\%$ load resistance change

4.20.4 This requirement is applicable over an output voltage or current range of 10 % to 100 % of rated output.

4.21 The differential and common-mode peak-to-peak output ripple voltages shall not exceed 0.3% of full rated output voltage from DC to 1 MHz under all operating conditions.

4.22 The 3 dB, small-signal voltage-regulation bandwidth shall be $\geq 1000$ Hz. The 3 dB, small-signal current regulation bandwidth shall be $\geq 200$ Hz.

4.23 Tracking and accuracy capability shall limit the error between any external programming voltage and the equivalent actual voltage or current output to 0.1 % of rated output. This requirement is applicable over an output range of 10 % to 100 % of rated output.

4.24 The Power Supply shall be capable of operating in series with another, similar Power Supply when configuring both Power Supplies as voltage sources as shown in Figures 5 and 6.

4.25 The Power Supply shall be capable of operating in parallel with another identical Power Supply when configuring both Power Supplies as current sources as shown in Figures 7 and 8.

4.28 Output over-voltage protection is not a requirement.

4.29 The Power Supply shall be capable of storage and operation from 0 % to 95 % relative, non-condensing, humidity.
5.0 PURCHASER’S REQUIREMENTS

5.1 The requirements below are applicable for the Power Supply configured as a constant voltage or constant-current source with the external current loop in the closed state. A switch on the power supply controller Chassis achieves the closed loop state.

5.2 Limit diurnal output load current deviation to \( \leq 2 \text{ ppm/°C} \) due to temperature changes over the range listed in Paragraph 2.1. Limit load current deviation to \( \leq 100 \text{ ppm} \) due to the cumulative effects of ambient temperature change and Power Supply ripple and line voltage or load resistance changes of \( \pm 1 \% \). These requirements are applicable over an output current range of 10 % to 100 % of rated output current.

5.3 Output current regulation shall be \( \leq 100 \text{ ppm} \) of full rated current output for a line voltage or load resistance change of \( \pm 5 \% \). The Power Supply current response shall achieve the above-specified current regulation within 500 \( \mu \text{s} \).

5.4 Tracking and accuracy capability shall limit the error between any external programming voltage and the equivalent actual current output to 0.1 % of rated current output. This requirement is applicable over an output current range of 10 % to 100 % of rated output current.

5.5 The 3 dB, small-signal current-regulation bandwidth shall be \( \geq 100 \text{ Hz} \).

6.0 TOPOLOGY AND FEATURES

6.1 The topology shall be off-line, switch-mode H-bridge inverter(s) driving a high frequency (16 kHz) line-to-load matching/isolation transformer. The rectified output of the inverter(s) shall drive Purchaser’s loads at the required output voltage and current levels.

6.2 An internal 100 \( \Omega \), \( \pm 5 \% \), 25 W ground resistor shall be provided and connected as shown in Figure 1. Ground current (voltage-sensing) monitoring shall be made across the resistor, NOT across the (-) output bus to chassis ground. If necessary, a suitable bypass capacitor shall be across the ground resistor.

6.3 The Power Supply input and output shall be isolated from each other and from case ground and shall satisfy the following dielectric requirements:

6.3.1 600VDC input to ground with any EMI suppression capacitors (\( \geq 600 \text{V rating} \)) disconnected from the input or from ground during testing. Maximum leakage current shall be \( \leq 200 \mu \text{A} \).

6.3.2 600VDC input to output with any EMI suppression capacitors (\( \geq 600 \text{V rating} \)) disconnected from the input and from the output during testing. Maximum leakage current shall be \( \leq 200 \mu \text{A} \).

6.3.3 500VDC output to ground with any EMI suppression capacitors and the ground resistor disconnected from the output or from ground during testing. Maximum leakage current shall be \( \leq 200 \mu \text{A} \).
6.4  An internal freewheeling diode shall provide a current path for safe magnet current decay and shall prevent reverse polarity voltage spikes when turning the Power Supply off. The current rating of this diode shall be the same as the Power Supply rated output current. A voltage reverse polarity due to magnet current discharge shall not damage Power Supply internal components.

6.5  Self-protect the Power Supply under any operating condition, such as; the output is suddenly open-circuited, sustains a prolonged overload, or short-circuits or any internal power-switching component fails.

6.6  A locally adjustable, front-panel mounted, multi-turn locking potentiometer shall provide output current limiting from 0% to 100% of rated output current.

6.7  Recovery from an over-current or output short circuit that causes the output current to be limited at the current-limit set point shall be automatic. In the event that the output current exceeds the current limit set point by $\geq 5\%$, an over-current trip shall latch and turn the supply off by opening its input contactor. Refer to Figure 1.

6.8  Connect permanent, redundant bleeder resistors across the terminals of any capacitor or capacitor bank that operates over 50V and stores more than 10J of energy. Size the resistors per NEC Article 460-6.

6.9  Input and output filter inductors and converter output transformers shall have Class H, 220 °C insulation. Actual core and winding temperature rises shall be limited to 50 °C and 125 °C, respectively.

7.0  **POWER SUPPLY/ CONTROLLER CHASSIS INTERFACE**

7.1  The Power Supply shall interface to the power supply controller Chassis provided by Purchaser. Below is the description of this interface.
7.2 Furnish the Power Supply with a subminiature-type D, 25-socket (female) contact connector. Place the connector at the rear of the Power Supply and designate it J1. Refer to Figure 3. The metal shell of the connector shall be in electrical contact with the Power Supply rear panel. All unused pins shall remain unconnected. J1 connector pins and functions shall be as shown in Figure 3 and listed below:

1. Program Output Voltage, Positive
2. Output Voltage Sense, Positive
3. Ground Current Sense, Positive
4. Power Supply Ready Status, Positive
5. Power Supply On Status, Positive
8. Reset for latched Power Supply Interlocks
10. Return for P. S. Reset and On Command, pins 8 and 9 (above)
14. Program Output Voltage, Return
15. Output Voltage Sense, Return
16. Ground Current Sense, Return
17. Power Supply Ready Status, Return
18. Power Supply On Status, Return

7.3 **Programming.** The output voltage or current shall be linearly programmable by means of an external analog signal of 0 to + 5 volts (J1-1 to J1-14). This signal shall have 2 kV isolation to allow reference to any point in the Power Supply. The differential input impedance shall be $\geq 1000\Omega$.

7.4 **Output Voltage Monitor.** The Power Supply shall provide an external analog output signal of 0 V to + 5 V (J1-2 to J1-15) with 0.1 % accuracy representing 0 to 100 % of full scale output voltage. Obtain this signal from taps on a voltage divider from the positive output terminal to the negative output terminal as shown in Figure 3. This signal shall have 2 kV isolation and the source resistance at J1 shall be less than 100 $\Omega$.

7.5 **Ground Current Monitor.** The Power Supply shall provide an external analog output signal (J1-3 to J1-16) proportional to ground current flowing through the internal 100$\Omega$ ground resistor. The signal shall be 0 V to ±10 V for a ground current of 0 to ±100 mA. The output impedance at J1 shall be $\leq 100\Omega$. If chassis-ground-based electronics are employed; the design shall limit ground current to $\leq 1\ mA$. This signal shall have 600V isolation.

7.6 **Power Supply Ready.** The Power Supply shall provide an external, active LOW signal (J1-4 to J1-17) when the Power Supply is ready to be remotely turned on. Provide this READY signal by the open-collector output of an internal optical isolator. The collector shall be capable of sinking 2 mA from a +24 V external source. The collector voltage shall not exceed 0.4 V at 2 mA in the LOW state. When connected to an external voltage source via a resistor, this signal shall be HIGH when the Power Supply internal auxiliary power is absent. The READY signal is a summation of all the Power Supply interlocks. If absent, it opens an electromechanical contactor (see Figure 1), inhibits IGBT gate pulses and prevents
operation. The READY interlock shall be latched in the tripped condition requiring a local manual reset before remote operation.

7.7 **Power Supply On Command.** Turn on the Power Supply output by an external, active HIGH input signal (J1-9 to J1-10). This signal is provided from a +5V source capable of sourcing 16 mA and shall be applied to the detector diode of an internal optical isolator. When this input signal is LOW, the electromechanical contactor shall open; the Power Supply shall cease switching operations and shall not provide any output.

7.8 **Power Supply On Status.** The Power Supply shall provide an external, active LOW signal (J1-5 to J1-18) when the Power Supply is on. Provide this signal by the open-collector output of an internal optical isolator. The collector shall be capable of sinking 2 mA from a +24 V external source. The collector voltage shall not exceed 0.4 V at 2 mA in the LOW state. When connected to an external source via a resistor, this signal shall be HIGH when the Power Supply is off.

7.9 **Power Supply Reset Command.** Reset the Power Supply interlocks by an external, active, HIGH input signal (J1-8 to J1-10). This signal is provided from a +5 V source capable of sourcing 16 mA and shall be applied to the detector diode of an internal optical isolator. Purchaser will provide a 100-millisecond pulse as part of the turn-on sequence. It will reset the interlocks listed in Paragraph 8.0.

8.0 **POWER SUPPLY INTERLOCKS**

8.1 The Power Supply shall minimally contain the latched, re-settable interlocks listed below. These interlocks and any additional interlocks required by Seller’s circuitry shall form a chain that, when broken, opens the input contactor, inhibits IGBT gate pulses and disables the Power Supply READY in the power supply controller Chassis.

8.1.1 Loss of phase or low/high AC input
8.1.2 DC output over-current
8.1.3 Chassis over-temperature

9.0 **CHASSIS**

9.1 Enclose the Power Supply in a chassis suitable for standard Electronic Industries Alliance (EIA) 19” rack mounting. Notch the front panel in the standard 1/4” by 1/2” slot with standard EIA slot spacing. The maximum front panel height shall be 5.75” (3U) as shown in Figure 9 for power supplies rated ≤ 2.5kW, 8.75” (5U) for power supplies rated 2.5kW to 15kW and 13.969” (8U) for power supplies > 15kW. Chassis depth shall not exceed 22”. Overall depth shall not exceed 25”. The chassis shall be steel or aluminum. If fabricated from aluminum, Alodine the front panel.

9.2 The front panel shall be painted Sherwin Williams Strobe White F-63-W-13 with black lettering. Silk-screen the output voltage and output current rating of the Power Supply on the front panel for visual identification. Designate the voltage value first. Leave the backside of the front panel unpainted for grounding purposes.

9.3 The front panel-mounted circuit breaker shall be as described in Paragraph 4.6.
9.4 Provide LEDs to indicate the following functions:
9.4.1 AC ON—green colored. Indicates that the front panel circuit breaker is closed
9.4.2 DC ON—red colored. Indicates that the internal contactor is closed
9.4.3 Any additional LEDs are at Seller’s discretion
9.4.4 Illuminate the front panel LEDs only when activating the function they represent. Provide a manual pushbutton to ascertain that the LEDs are functional. Depressing this pushbutton shall not reset any fault interlocks.

9.5 Provide a 3-digit, red LED voltmeter and a 3-digit, red LED ammeter on the front panel. The meter readouts shall be accurate to 1% of full-scale over the operating range of the Power Supply.

9.6 Provide a ten-turn locking potentiometer for linearly setting the output current limit threshold from 0% to 100% of full rated output on the front panel.

9.7 Purchaser will locally control the Power Supply with a Control Box that plugs into the Purchaser-furnished power supply controller Chassis. Purchaser will furnish the Control Box to Seller for factory testing of the Power Supplies.

9.8 The chassis rear panel shall minimally contain the following connectors:
9.8.1 480 VAC power
9.8.2 J1 the power supply controller Chassis interface
9.8.3 J2 the Dummy Plug interface (Seller shall also provide P2, the mating dummy plug).
9.8.4 DC output power

9.9 For Power Supplies rated from 2.5 kW to 15 kW, use #10 AWG minimum wire to connect the AC input plug. The plug itself shall be:
9.9.1 NEMA L21-30P (5-wire) for 208 VAC input power supplies, regardless of whether or not the neutral wire is used.
9.9.2 NEMA L22-30P (5-wire) for 480 VAC input power supplies, regardless of whether or not the neutral wire is used.

9.10 Power Supplies rated 22.5 kW may have an AC input terminal block on the rear of the chassis, and in this case, mount the terminal block inside a box with a cover plate. Size wiring accordingly with the maximum input AC current.

9.11 Wire connections shall be made in accordance with the plug (or terminal block) manufacturer’s instructions. Termination screws shall be tightened to the plug manufacturer’s specifications using a calibrated torque wrench. A QA traveler shall accompany the Power Supply to ensure that the plug and mating wires have been properly terminated.

9.12 The DC output terminals shall meet IEEE standards appropriate for the Power Supply output current rating, including lug hole size and spacing. Each cable terminal shall be capable of withstanding 150 ft-lbf of tightening torque and a vertical load of 50 lbs. Purchaser’s cables will approach and attach to the Power Supply from the bottom. The DC output terminals shall have a 90° bend as shown in Figure 10, or be mounted with vertical
9.13 For electrical safety, openings in any surface shall be 1/4 inch maximum in one dimension. If forced air cooling is required, the air intake shall be from the front and exhaust shall be to the rear. Fans and/or blowers within the Power Supply shall have sealed ball or needle bearings for long operating life.

9.14 The Power Supply shall have thermal protection that turns the Power Supply off (opens the input contactor) if the internal temperature exceeds a factory preset value. Recovery from an over-temperature condition shall occur by RESET as defined in Paragraph 7.9.

9.15 The Power Supply shall have easily identified internal test points for troubleshooting and ease of maintenance.

9.16 Affix an identification nameplate to the rear panel shown in Figure 10. The nameplate shall contain the following minimum information:

9.16.1 Manufacturer name, address telephone number and web address

9.16.2 Manufacturer model number, serial number, and manufacture date

9.16.3 The number of this Specification and revision

9.16.4 Input voltage

9.16.5 Rated output voltage and current

9.16.6 Weight

10.0 NOISE

10.1 The audible noise emitted from the Power Supply under any load operation shall not exceed 63 dBA when measured 3 feet from the Power Supply.

11.0 MAINTENANCE

11.1 Electrically and mechanically design the Power Supplies for ease of maintenance. Critical monitoring points shall be made available for oscilloscope or instrument monitoring through appropriate connectors. The H bridge inverter shall be mechanically configured so it can be removed as a unit and easily replaced by another to minimize down-time.

12.0 EMC AND RELIABILITY

12.1 Design the Power Supply to meet the conducted emission limits of FCC Rules, Part 15, Class A for noise conducted onto the AC input lines.

12.2 When 2 to 5 Power Supplies are mounted in an EIA rack with no separation between stacked units, each Power Supply shall operate properly without noise interference or cross-talk from the other Power Supplies.

12.3 The predicted mean time between failures (MTBF) of the Power Supply shall be ≥ 100,000 hours when calculated in accordance with a MIL-HDBK-217F under a ground fixed and benign environment at a 50 deg. C ambient temperature. Unless otherwise specified, the component de-ratings tabulated below apply for an ambient temperature of + 50 °C.
### 13.0 WORKMANSHIP

13.1 All printed circuit boards shall be acrylic conformal coated per IPC-CC-830A.

13.2 The Power Supply shall be UL recognized or shall meet UL 1950 or, as a minimum, shall utilize UL recognized components. The Power Supply shall comply with UL 94 for flammability of plastic materials.

13.3 Route wires away from sharp edges, screw threads, burrs, fins, moving parts, drawers and similar parts that can abrade the wire insulation. Route wires away from heat-producing components, such as heat sinks of power circuit components, power supplies, transformers, cabinet heaters, and power resistors.

13.4 The chassis shall have provision for grounding all exposed, non-current carrying metal parts that persons can contact during normal operation or adjustment of the equipment and that can become energized due to a breakdown of insulation, loose wiring connections, or electrical disturbance.

13.5 The Power Supply grounding terminal shall have electrical continuity with all metal parts of the enclosure by means of metal-to-metal contact or by means of an internal bonding conductor. Size the bonding conductor as specified in table 15.1 of UL 508A, or the size of the field wiring conductor supplying the Power Supply, whichever is smaller.

13.6 Mechanically secure all internal wiring terminations, provide electrical continuity, and ensure that no loose strands protrude from the connection.

13.7 Securely mount components to a supporting surface. A bolt, screw or other part used to secure a part of a component shall not also secure the component to the supporting surface.

13.8 Secure an un-insulated live part, including a terminal, or a component with un-insulated live parts, to its supporting surface by a method other than by friction or tie wraps to prohibit it from turning or shifting in position.

13.9 Spacing between un-insulated live parts of adjacent components, between un-insulated live parts of components and grounded or accessible dead-metal parts, between un-insulated live parts of components and the enclosure, and at field wiring terminals shall be maintained as shown in Table 10.1 and Table 10.2 of UL 508A.

<table>
<thead>
<tr>
<th>Component Type</th>
<th>% Voltage</th>
<th>% Current</th>
<th>% Power</th>
<th>Other Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semiconductors</td>
<td>≤ 50</td>
<td>≤ 50</td>
<td>≤ 50</td>
<td>T_j ≤ 110°C</td>
</tr>
<tr>
<td>Resistors</td>
<td>≤ 50</td>
<td>≤ 50</td>
<td>≤ 50</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Capacitors</td>
<td>≤ 50</td>
<td>≤ 70 (RMS ripple)</td>
<td>Not applicable</td>
<td></td>
</tr>
<tr>
<td>Electromechanical</td>
<td>≤ 85</td>
<td>≤ 80 (resistive)</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
</tbody>
</table>
14.0 QUALITY ASSURANCE

14.1 LCLS shall have the right to reject, as not in conformity with the requirements of the Purchase Order, any equipment or services for which all required reports, procedures or certifications are not delivered. Seller’s failure to deliver such documents or delivery of deficient documents is a failure to make delivery.

14.2 Seller shall provide and maintain a quality program/system that complies with any recognized U.S. Quality Program/System Standard in effect on the date of Purchase Order placement. Typical examples are ISO 9001, MIL-I-45208 and ANSI N45.2 or other equivalent.

14.3 Seller shall require, in writing, all tier subcontractors to comply with all applicable quality program/system requirements. The quality system and control of Seller’s “Special Processes” and all tier subcontractors to the extent practicable shall be subject to audit by LCLS representatives.

14.4 Seller shall tender for acceptance only equipment or services that have been inspected and tested in accordance with its quality program/system and have been found to conform with Purchase Order requirements.

14.5 Bidder shall submit with his proposal evidence of his quality program/system. Such evidence may consist of a copy of the Bidder’s approved QA/QC Manual, a QA/QC Plan, or a combination thereof, and shall specify the standard(s) upon which the system is based.

14.6 Prior to the performance of any operations involving the following, but in no event later than 30 calendar days after the Purchase Order date, Seller shall deliver for LCLS review and written approval:

14.6.1 A concise explanation of all manufacturing processes and assembly procedures.

14.6.2 An Inspection and Test Plan. The plan shall specify, as a minimum:
   a. What is to be inspected (e.g.; components, subassemblies and assemblies).
   b. The inspection/tests to be performed
   c. The inspection/test methods or procedures used.

14.6.3 A description of how the purchased equipment will be marked and identified

14.7 LCLS will notify Seller of its approval or disapproval within 30 calendar days. If notice is not issued within such time, Seller’s procedure shall be deemed approved.

14.8 When deemed necessary, LCLS will conduct a pre-award survey of a prospective Seller’s technical, quality assurance, production, or financial capability. Evaluation of documented quality assurance program/system applicable to materials produced by Seller may include, but will not be limited to, inspection and test controls, calibration of measuring and test equipment, special process controls, material storage and handling and drawing change controls.
14.9 All design drawings and specifications for the purchased equipment shall contain all details necessary for LCLS complete analysis of Seller’s design and compliance with Purchase Order requirements. Submit the design drawings and specifications to LCLS within 8 weeks after Purchase Order award for LCLS review and acceptance.

14.10 If LCLS disapproves Seller’s design drawings and specifications, upon LCLS written request, Seller shall submit revised design drawings and specifications for LCLS review. Upon receipt of each request, Seller shall make any necessary changes, modifications, or additions to the design drawings and specifications. All costs related to the preparation and submission of revised design drawings and specifications shall be borne by the Seller. LCLS reserves the right to require an equitable adjustment of the Purchase Order price for any extension of the delivery schedule or from any additional costs to LCLS arising out of Seller's failure to deliver complete design drawings and specifications conforming to the requirements of the Purchase Order.

14.11 Notwithstanding the inspection requirements of the Seller’s facilities, final acceptance of the purchased equipment will take place following delivery to, and testing by, LCLS.

14.12 LCLS reserves the right to perform any or all tests required to verify that the purchased equipment conforms to the requirements of the Purchase Order. Failure of any of the tests performed will deem the Purchased equipment unacceptable. LCLS will return the Purchased equipment to Seller for replacement at no cost to LCLS. Shipping costs of return and replacement shall also be borne by Seller.

14.13 Obtain and make available for inspection by LCLS, certifications of all materials used in the manufacture of the Purchased equipment. Certification shall be in the form of original source test reports of mechanical properties, chemical composition, or other requirements called out in the Purchase Order.

14.14 Certify that equipment and materials furnished under the Purchase Order are free from the use of suspect/counterfeit materials.

14.15 Allow SLAC representatives full access to Seller's facility as stipulated in the “Quality Assurance Requirements.”

15.0 **RELEASE FOR FABRICATION**

15.1 Seller shall provide the below-listed documents, drawings, and calculations to Purchaser for review and approval 30 days prior to release of the Power Supply for fabrication. Sufficient detail shall be provided to enable Purchaser evaluation. Purchaser might request a conference with Seller at Purchaser's facility for clarification of design details.

15.1.1 Outline drawings of the Power Supply chassis showing to-scale plan and profile views. The drawings shall show major features, dimensions and total assembly weights.

15.1.2 Outline drawings of the Power Supply detailing, locating, and dimensioning all components and accessories.

15.1.3 Electrical wiring diagrams of the power, control, monitoring, and interlock circuits.
15.1.4 Calculations of actual vs. rated voltage, current and power for all power components.
15.1.5 Calculations of the expected temperature rise of all power components.
15.1.6 Reliability calculations.
15.1.7 Nameplate information.
15.1.8 A Gantt chart outlining the main steps on the design, construction, testing, documentation, and delivery.

16.0 FACTORY ACCEPTANCE TESTS
16.1 Seller shall submit an acceptance test procedure to Purchaser for approval at least 30 days prior to the start of the factory tests. The procedure shall include the tests described below and in the sequence listed below.
16.2 Perform the following acceptance tests on each Power Supply:
16.2.1 Electric dielectric withstand and isolation between input and output, between input to ground and output to ground
16.2.2 Loss of input phase protection, and interlock action when the AC input voltage drops below 30% of nominal line value.
16.3 Subject one of each Power Supply rating to a 72 hour elapsed time, room ambient temperature, nominal line, “burn-in” at rated voltage and current output. After every 22 hour operating period, the AC input to the Power Supply shall be turned off for 2 hours and then turned back on for another 22 hours. Any failures during the burn-in shall be documented, corrected and the 72 hour burn-in repeated. Ambient temperature shall be recorded during testing.
16.4 Following the burn-in test, subject one of each Power Supply rating to a non-operating sinusoidal vibration sweep from 10 Hz to 100 Hz at 2 G for a period of 30 minutes in the y–axis (top-to-bottom).
16.5 Following the vibration tests, test one of each Power Supply rating for:
16.5.1 Output voltage ripple at maximum input voltage and 10% output voltage and current.
16.5.2 Output voltage ripple at minimum input voltage and 100% output voltage and current.

17.0 DOCUMENTS ACCOMPANYING DELIVERY
17.1 Seller shall furnish the below-listed documentation to Purchaser as part of the Power Supply delivery.
17.1.1 “As-approved,” editable versions of the drawings listed above in electronic format.
17.1.2 A complete parts list of all electronic components. For Seller in-house part numbers, either the generic part number of an equivalent industry standard replacement or all technical selection criteria shall be provided.
17.1.3 The test reports from the factory acceptance tests listed above, certified by Seller’s Quality Assurance Manager.
17.1.4 An “as-approved” version of the packing, shipping, handling, and installation procedure in electronic media.
17.1.5 A list of critical spare parts and Seller-recommended quantities to be kept on-hand. The spare parts list shall minimally show IGBTs and IGBT gate driver boards, freewheeling diodes, fuses, relays, panel meters, current transducers, filter capacitors, printed circuit board assemblies, chokes.


17.1.7 The predicted MTBF data and analysis.

17.1.8 Preferably draw electrical drawings using Protel and mechanical drawings using AutoCAD, Microstation, or Solid Edge. Editable Adobe portable document format (PDF), or Word is acceptable for all other documents.

18.0 PACKAGING, SHIPPING, HANDLING AND INSTALLATION

18.1 Seller shall submit a proposed packing, shipping, handling, and installation procedure in electronic format to Purchaser for review and approval 30 days prior to the scheduled shipment of the Power Supply.

18.2 The Power Supply shall be shipped completely assembled and must be able to withstand shock and vibration incidental to shipment and handling by common carrier.

18.3 All equipment shall be suitably packed, rigidly crated, braced and protected against weather, damage or undue strain. Subassemblies or panels shall be braced for shipment. Instruments relays, regulators or other fragile parts shall be braced and protected individually.

18.4 All shipping boxes shall be suitable for unloading and transferal by the Purchaser using a fork lift.

18.5 Seller shall notify Purchaser 10 days prior to shipment and shall provide a packing list that identifies the contents of each box or crate and its estimated weight.
18.6 No Power Supply shall be shipped until all factory tests, analyses and inspections have been completed and the Purchaser has approved the test reports.

18.7 Upon receiving the Power Supplies, the Purchaser will proceed with a through internal inspection of all units to check for the integrity of the connections and internal wiring. See the SLAC Electrical Equipment Field Report for the list of items subject to examination. This internal inspection shall not invalidate the warranty.

19.0 PURCHASER’S TESTS AND ACCEPTANCE

19.1 Final inspection and testing will be done by Purchaser after Power Supply installation at the SLAC SSRL facility. The Power Supply will be connected to the actual magnet load and subjected to the tests listed below:

19.1.1 Correct operation of all indicators, controls and interlocks.
19.1.2 Heat run for 72 hours at 100 % load and maximum ambient temperature.
19.1.3 Power factor and efficiency at full rated load.
19.1.4 Output current drift over time and temperature.
19.1.5 Response to line and load perturbations.
19.1.6 Output voltage ripple at 10 % and 100 % output current.

19.2 For the purpose of warranty under an order for the Power Supplies, the final acceptance is defined as the successful completion of acceptance tests at the Purchaser’s site to substantiate the compliance of the Power Supplies with these Specifications.

19.3 Should the Purchaser’s tests substantiate the fact that the Power Supplies do not comply with the requirements in this Specification, the vendor shall, at his own expense, make changes, additions, and further tests within a reasonable time to fully comply. The vendor shall also be responsible for shipping and handling costs associated with the problem resolution.

19.4 Purchaser’s acceptance of the Power Supplies is contingent upon receipt of the “as-approved” final documentation required by Paragraph 16.
Figure 1 – Power Supply Conceptual Diagram
Figure 2 – Topology for a Single Power Supply

All external cables by Purchaser
Figure 3 – Power Supply Controller to Power Supply Interface

To and from Purchaser’s Ethernet chassis
Figure 4 – J1 and J2 Connections

Figure 4 from Specification 1.2-152
New connections shown in red

Sellers shall not use empty pins

+VREF → 1
-VREF → 14
+VOUT → 2
-VOUT → 15
+IGND → 3
-IGND → 16
+READY → 4
-READY → 17
+PS ON → 5
-PS ON → 18
NO CONNECTION → 6
NO CONNECTION → 19

7
20
8
21
9
22
10
23
11
24
12
25
13

Purchaser’s Ethernet Cable
P1

POWER SUPPLY

J1

Seller’s Dummy Plug
P2

POWER SUPPLY CONTROL CIRCUITS

(-) Output
Bus

To Purchaser’s MPS

In for CV
Out for CC

RESERVED

New connections shown in red
All external cables by Purchaser

Figure 5 – Series Connected Power Supply Topology
Figure 6 – Series Connected Power Supply Control
Figure 7 – Parallel Connected Power Supply Topology
Figure 8 – Parallel Connected Power Supply Control
Figure 9- Power Supply Front Panel
Figure 10 – Power Supply Rear Panel