CLSI Magnet Power Supply Specification

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1. INTRODUCTION

1.1 Purpose

This document specifies the requirements of magnet power supplies used at the Canadian Light Source Inc. (CLSI). D.C. current regulated type power supplies are required to supply electromagnet loads which have typical time constants in the range from 20 ms to 2500 ms.

1.2 Scope

The Proponent will furnish all equipment, materials, tools, facilities, and labour to perform all the work necessary to design, manufacture and test the D.C. power supplies as per this specification. This work includes, but is not limited to:

- Materials
- Equipment
- Commercial components
- Detailed drawings
- Operation and maintenance manuals
- Fabrication
- Assembly
- Testing and Inspections
- Quality Assurance /Quality Control documentation
- Delivery to site
- Warranty

1.3 Background

The Canadian Light Source, CLSI, is a national facility operating on the University of Saskatchewan campus in Saskatoon, Saskatchewan. This facility is a 3rd generation synchrotron light source, which produces a high intensity source of infrared, visible, ultraviolet and x-ray radiation.

Electromagnets are used to bend and focus the electron beam which produces the synchrotron light. Since stability of this beam is crucial for acceptable operation of the facility, the power supplies for the magnets will typically have very tight tolerances on the DC output current regulation.

1.4 Definitions

1.4.1 **ANSI** American National Standards Institute

1.4.2 **DCCT** Direct Current Current Transformer

1.4.3 **DCS** Distributed Control System

1.4.4 **IEEE** Institute of Electrical and Electronics Engineers

1.4.5 **NEMA** National Electrical Manufacturers Association

1.4.6 **CSA** Canadian Standards Association

1.4.7 **PLC** Programmable Logic Controller

1.4.8 **RMS** Root Mean Square

1.4.9 **EPICS** Experimental Physics and Industrial Control System

1.4.10 **Regulation** shall be referred to rated power supply output. Unless specified regulation shall include line, load, ripple, thermal, short term and long term drift. Regulation shall be defined as peak to peak deviation from the DC average current value.

2. POWER SUPPLY REQUIREMENTS

This section of the specification describes the performance and physical characteristics of the units required. Alternate products or schemes offered by the Proponent that may provide equal or better performance and reliability may be considered, but shall be subject to review and acceptance by CLSI.

2.1 General Requirements

2.1.1 The power supplies shall be completely assembled units that can be installed and interfaced to remote CLSI control computers.

2.1.2 Power supplies are grouped into two broad classes. The first class has an output which changes relatively infrequently. These are typically adjusted during a set-up procedure then left at that setting during operation. The second class has outputs that vary continuously, as would be required for a dynamic orbit correction system.

2.1.3 Specific power supply requirements shall be summarized in the form shown in 3.1 Sample Power Supply Requirements Summary.

2.1.4 The proponent shall complete the form shown in 3.2 Proponent Data Sheet for each type of supply as part of the proposal.

2.1.5 When room numbers are indicated in the Power Supply Requirements Summary the supply is intended to be installed in a particular area of the facility. Supplies with different room numbers shall be independent of each other.

2.1.6 Pricing shall be provided for each rating listed in the Power Supply Requirements Summary. If multiple ratings are to be provided from one supply a total price for the combined unit should also be provided.

2.2 Functional Requirements

2.2.1 As a minimum, each power supply shall consist of an input circuit breaker, line contactor, rectifier transformer, full-wave rectifier, DC passive filter, current regulation circuit, precision current measuring device, voltage measuring device, control and protection circuits. If an off-the-shelf supply is to be used and the supply is not available with an input circuit breaker, input fuse(s) may be used instead.

2.2.2 Current regulated power supplies shall include a local current limit potentiometer. This limit shall be adjustable from less than 20% to 100% of rated output. The current limit control shall be easily accessible and verifiable to ±5% by either potentiometer dial settings or a local digital display.

2.2.3 Unipolar current regulated supplies shall be adjustable from 0 to 100% of maximum rated output.

2.2.4 Bipolar current regulated supplies shall be adjustable from maximum rated output, through 0, to the maximum rated output at the opposite polarity while driving an inductive (magnet) load. Polarity reversal switches shall not be used unless noted in the Power Supply Requirements Summary.

2.2.5 Four quadrant current regulated supplies shall be adjustable from maximum rated output, through 0, to the maximum rated output at the opposite polarity while driving an inductive (magnet) load. Rapid adjustments to current output, as specified in the power supply description, are required so the effects of magnet inductance are significant. These supplies must be capable of supplying and sinking all rated current levels into both positive and negative voltage polarity loads at all levels from the maximum negative to the maximum positive voltage ratings.

2.2.6 A supply may have more than one output channel, with the outputs sharing the input transformer and rectifiers (bulk DC), and an electrically connected (common) output connection. Individual lugs for all outputs shall be provided.

2.2.7 The load output channels shall not be connected directly to ground or the frame. Ground fault detection circuitry may be disconnected from ground during the high voltage tests described in Section 2.8.

2.2.8 AC input power will be supplied through a CLSI-installed, external, manually operated disconnect switch or breaker. It will be possible to lock this switch in the OFF position so no power is fed to the supply, in compliance with CLSI lock out procedures.

2.2.9 The electrical power supplied by CLSI will be 60 Hz AC. Each load connection shall be one of the voltage levels listed and not exceed the current limits given in Table 1.

Table1: Load Connections

RMS voltage (V,+/- 10 %)	Single or Three Phase	Maximum RMS current (A)
120	Single	15
208	Single	15
208	Three	30
600	Three	1900

Line voltage will exhibit instantaneous (< ½ cycle) fluctuations of +/- 1.5 % and gradual variations of +/- 10 %. Brownout conditions involving instantaneous drops and restorations of 10 % are also observed.

2.2.10 Depending on the intended installation power supplies will use either 120 V, 480 V, or 600 V Delta AC distribution as specified in the Power Supply Requirement Summary.

2.2.11 Bolted busbar, fuse, and SCR joints shall use Belleville washers, flat stainless steel washers, lock nuts, and a joint compound reviewed and accepted by CLSI.

2.2.12 DC busbars and output terminals shall be silver plated and drilled to take standard NEMA fasteners. Anticipated cable sizes are presented in the Power Supply Requirements Summary. Adequate spacing shall be provided for corresponding NEMA cable lugs.

2.2.13 The circuit breaker on the power supply shall have an interrupting capacity of at least 65,000 A AC symmetrical RMS for the 600 V inputs and 5000 A RMS for the 120/208 V inputs as applicable. This breaker shall provide the following protection:

1. Instantaneous trip on primary circuit faults (phase-to-phase and phase-to-ground faults).
2. Delay to avoid false trips on turn on in-rush current transients.
3. Overload trips between 105-120% of rated load with a must trip level of 125% rated load.

2.2.14 The contactor on the power supply shall be rated for greater than 10^5 operations at 110% of full load.

2.2.15 The contactor should be equipped with at least two convertible auxiliary contacts. One should be connected to the power supply control system so external CLSI computers can monitor it. The other should be brought to a terminal strip for CLSI use.

2.2.16 All supplies with an input power requirement exceeding 2.5 kVA shall incorporate circuitry to reduce harmonic current components on the supply lines. As a minimum, this performance of this circuitry shall be the equivalent of 12 pulse rectification (refer to ANSI/IEEE Standard 519-1992).

2.2.17 The use of liquid dielectrics (high voltage oil) as an insulator should be avoided. A major disadvantage of oil is the possible contamination of CLSI UHV vacuum system when oil is used in close proximity. The use of oil may require a more elaborate fire protection system (CO_2 system and fire rated service room) to comply with the Canadian Electrical Code and National Building Code of Canada. If required, capacitors filled with flammable liquids shall limit the volume of the liquid to 14 litres or less and comply with the Canadian Electrical Code requirement 26-012 part (4). All required fire protection systems resulting from the use of liquid dielectrics shall be the responsibility of the Proponent. Any use of oil shall be subject to review and acceptance by CLSI.

2.2.18 The transformers used shall conform to the following specifications:

1. The rectifier power transformer shall be built with copper windings.
2. No splices shall be allowed.
3. The transformer shall be dry type.
4. The insulation shall be preferably IEEE class 180 (class H) or IEEE class 155 (class F).
5. The transformer shall be braced for rectifier service and shall be able to withstand the worst case fault currents that are available.
6. The unit shall be air cooled. Water cooling shall not be used.
7. It shall withstand input voltages of 110% of nominal without overheating.
8. Three phase primary windings shall be delta connected.
9. The transformer shall have an electrostatic shield between primary and secondary windings. The shield shall be connected to an insulated conductor brought out and connected to the single point signal ground.
10. All transformer connections shall be clearly marked.
11. The transformer shall conform to applicable subdivisions of ANSI standard C57 and all applicable CSA standards.

2.2.19 The DC passive filter shall be designed so that the unregulated DC voltage overshoot at turn on does not exceed 50%. Sudden simultaneous changes to all current setpoints from maximum to minimum shall result in less than 80% overshoot. Semiconductors and capacitors shall not experience more than 80% of their manufacturer's maximum voltage or current rating during these transients.

2.2.20 Voltage limiting devices or snubber circuits shall be placed across each rectifier cell and power semiconductor device. The snubber circuits should be adequate to limit the voltage transients experienced by the semiconductors during normal operation to no more than 60 % of the manufacturer's voltage rating.

2.2.21 The filter choke insulation shall be IEEE class 180 (class H) preferably, or IEEE class 155 (class F).

2.2.22 Filter capacitors shall be computer grade, rated for an operating temperature of at least 85 ºC. The filter network shall be designed so that the normal maximum RMS ripple current does not exceed 50% of the capacitor ripple current rating at the rated operating temperature. For supplies with three phase AC feeds, normal ripple current includes ripple current resulting from a phase voltage mismatch of up to 5%.

2.2.23 The filter capacitor bank shall be protected with an RMS ripple current sensing/interlock circuit. The trip level shall be adjustable from <50% to >100% of the rated capacitor RMS current and shall be preset to 70%.

2.2.24 Thermal interlock switches shall be mounted on all heat sinks and used as interlocks by the power supply control system.

2.2.25 The junction temperature of any power semiconductors shall not exceed 100^{o} C with an ambient temperature of 40^{o} C and with cooling water at maximum temperature and minimum flow rate. Thermal interlock switches shall be used to open the primary contactor before the maximum junction temperature of 100^{o} C is reached.

2.2.26 Unipolar supplies should have a reverse connected diode across the DC output terminals. This diode provides a short circuit current path for the continuing inductive load current upon turn-off. The diode shall be capable of operating continuously at the power supply full rated DC current. This diode shall be mounted on an adequate heat sink to allow it to be operated at this level continuously without exceeding its thermal ratings. This diode shall not be fused.

2.2.27 Power semiconductors, except for the free wheeling diode, should be individually fused. If power semiconductor circuits are operated in parallel, the supply shall have provision for detecting if fuses have blown, and for limiting the operation so the remaining semiconductors are operating within their manufacturer's rated safe operating area.

2.2.28 Power supplies with greater than 2 kW output shall include water cooled semiconductor heat sinks unless natural convection air cooling is sufficient. Forced air cooling should be avoided. Alternate cooling schemes shall be subject to review and acceptance by CLSI.

2.2.29 If applicable, and unless otherwise stated, the Proponent shall supply water temperature and flow monitoring transducers. These shall be incorporated in the power supply control system

2.2.30 Unipolar capacitors shall be protected against reverse charging.

2.2.30.1 All wiring shall have a minimum insulation rating of 600 V. Wiring used for 600 V power shall have a minimum insulation rating of 1000V.

2.2.31 The Proponent shall supply all cooling water supply and return manifolds for the system. There shall be only one inlet and outlet connection to the supply or group of supplies.

2.2.32 Enclosures should be designed to reduce and limit electromagnetic radiation from the supply. Doors and removable panels shall use a grounding conductor to bond them to the rest of the frame. The use of copper finger stock, or wire knitting or braiding to improve connectivity between doors, panels, and the frame is encouraged.

2.3 Control System

2.3.1 Proponents may elect to control several power supplies with one control system unit, provided the supplies are housed in close proximity to each other.

2.3.2 If the power supply is powered by a voltage over 208 V control power shall be derived from an external 120 V AC control power feed.

2.3.3 Provisions shall be made for remote control and monitoring by CLSI computers. The control system shall be designed to interface with CLSI Distributed Control System. The interface may use EPICS communication protocols, Modbus TCP/IP, or Profibus. Designs using RS-232 protocols may be considered, but shall be subject to review and acceptance by CLSI. Unless explicitly stated, all control and monitoring shall conform to the “Control System Technical Specification“[1]. The interface shall be subject to review and acceptance by CLSI before being implemented.

2.3.4 As a minimum, provision should be made for remotely monitoring the following:

- Operational state
- All interlock inputs
- Output Current
- Output Voltage
- If applicable, Cooling water flow
- If applicable, Cooling water temperature

2.3.5 All control and interlock signal inputs shall be 24 V DC and shall require less than 50 mA drive and use optical or some other form of isolation. Interlock inputs shall be designed to be fail safe; the presence of 24 V indicates the interlock condition is good. If applicable, On/Off control shall be designed so that a transition from 0 to 24 V turns the supply on and a transition from 24 to 0 V turns the supply off.

2.3.6 All control and interlock signal outputs shall be 24 V DC and shall be able to switch a minimum of 50 mA and use optical or some other form of isolation. Interlock outputs shall be designed to be fail safe; outputs provide 24 V when the interlock condition is good.

2.3.7 The Proponent shall provide electronic copies of all PLC control software programs, if a PLC is included in the design.

2.3.8 Controller hardware and software interfaces shall be reviewed and accepted by CLSI to verify adherence to CLSI control protocols and standards.

2.3.9 Indicator lights and status bits shall indicate true operation, not just control activity.

2.3.10 The protection devices and circuits on all power supplies shall be properly isolated from the main power circuits.

2.3.11 Where applicable, the following interlocks shall be incorporated in the power supplies and where indicated shall be redundantly used by the power supply control system and used to de-energize the main contactor directly without intervention by the control system.

1. Door/Panel microswitches – wired directly to main contactor coil; these should have a manual bypass capability which is automatically reset when the door is closed.
2. Cubicle over temperature – wired directly to main contactor coil
3. Ground fault – wired directly to main contactor coil
4. Control power failure – wired directly to main contactor coil
5. Local Emergency Off (mechanical latching pushbutton) – wired directly to main contactor coil
6. DC over current
7. Cooling water flow failure
8. Cooling water overtemperature
9. Transformer/choke over temperatures
10. Semiconductor/heat sink over temperature
11. Regulator failure
12. Phase loss/phase current imbalance
13. Filter capacitor ripple overcurrent
14. Magnet cooling water flow failure (1/output channel)
15. Magnet over temperature (1/output channel)
16. Two external (customer) interlocks, with +24 V indicating main contactor can be energized and 0 V causing the power supply to enter the FAULT or OFF state.

2.3.12 All individual power supplies shall have a minimum of four operational control command states. These should be OFF, FAULT, STANDBY, and ON. Where practical the power supply state machine shall be based on CLSI Control System Reference State Machine shown in section 3.3.

ON	The ON state energizes the power supply main contactor and output power is made available. The supply should be able to enter the ON state from the STANDBY or the OFF state with an ON command.
STANDBY	In the STANDBY state, the low level regulation and control circuitry will be energized but not the main contactor. All interlocks (internal and external) must be satisfied for the supply to be in the STANDBY state. The supply is ready to be turned ON. The unit should be able to be changed from the ON state to the STANDBY state with a STANDBY command. A RESET should clear all latched faults that are specific to the power supply and allow the unit to enter the STANDBY state if all interlocks are satisfied.
FAULT	The FAULT state will indicate that a fault has occurred during power supply operation. Additionally, if the supply is requested to enter the ON or STANDBY state from the OFF state, the supply will enter the fault state if all internal and external interlocks are not satisfied. All faults shall be displayed locally.
OFF	Control unit power shall not be de-energized in the OFF state; it will be used for status monitoring during the OFF state. The supply should be able to be turned off from any other state.

2.3.13 The Proponent may implement other operational states such as a WARNING state or a STARTUP state. These deviations from this specification on the operational states of power supplies are subject to review and acceptance by CLSI.

2.3.14 All interlocks status and alarm information shall be latched when a FAULT condition occurs. This information shall be monitored by the internal power supply control system and be available for readout by CLSI distributed control system.

2.3.15 The status of the power supply shall be displayed locally. The front panel shall provide indicators showing, as a minimum, the state of the power supply operation including FAULT, STANDBY, and ON and output voltage and current.

2.3.16 If applicable, local indicators shall use LED devices instead of incandescent bulbs.

2.3.17 If applicable, local indicators shall use green to indicate a good state. Red indicators shall be used to indicate faults. The preferred colour for intermediate conditions is yellow. If a multicolour LED is not used an unlit LED can be used to indicate the condition is not present.

2.3.18 If applicable, it is desirable that local pushbuttons use illuminated pushbuttons, green for the ON command, red for the OFF command, and yellow for RESET. It is also desirable that the ON pushbutton have a vertical bar, and the OFF pushbutton have a round 0 approximately ½ the diameter of the pushbutton.

2.3.19 The design of the control system shall be fail-safe. On a loss of control power the power supply shall safely trip OFF. Upon return of power, the power supply shall remain in the OFF state.

2.3.20 The interlocks and indication system shall be subject to review and acceptance by CLSI.

2.4 Performance

2.4.1 All power supplies shall perform in a stable fashion and exhibit no evidence of oscillation over their entire operating range. For flexibility they should also be able to drive loads smaller than the nominal load listed in the Power Supply Requirement Summary.

2.4.2 All power supplies shall regulate against instantaneous (< ½ cycle) line voltage fluctuations of ± 1.5% and gradual variations of ± 10%. The supply shall regulate in a derated mode during short term (< 2 seconds) brownout conditions involving instantaneous line voltage drops and restorations of up to 10%. In the derated mode output regulation tolerances can be increased by 50 ppm.

2.4.3 Any power supply control system shall respond to a change in the interlock status in less than 25 ms. Response times to user inputs should be less than 150 ms so that the user perceives immediate response.

2.4.4 All power supplies with an output greater than 1 kW should have an efficiency in excess of 90 percent and a power factor in excess of 0.9 at all power output levels greater than 80%. The Proponent shall provide information at the time of bid as to the expected efficiency and power factor of the power supply. Preference will be given to a supply with a higher efficiency.

2.4.5 Every effort shall be made through careful design to keep the acoustic noise levels below 60 dBA measured at a distance of 1 meter from the supply cabinet. Noise levels above 60 dBA limits effective communication and warning sounds such as sparking are masked.

2.4.6 All equipment/structures shall conform to the BKL report "Vibration Isolation Mechanical Equipment".

2.4.7 A local emergency off switch with mechanical latching shall be provided for each supply or group of physically connected supplies. This system shall employ redundant and independent means of shutdown including a hardwired connection to deactivate the main contactor coil.

2.4.8 Air cooled shunts may be used for supplies requiring no better than 100 ppm regulation. Water cooled shunts shall not be used for any supplies.

2.4.9 All supplies that require 100 ppm or better regulation shall include an isolated DC current transformer (DCCT) to provide the current feedback signal.

2.4.9.1 For power supplies with regulation requirements from 10 to 100 ppm the DCCT shall have an accuracy better than 10 ppm.

2.4.9.2 The DCCT for supplies with regulation requirements better than 10 ppm shall have an accuracy better than the required regulation.

2.4.9.3 The DCCT shall have a –3 dB bandwidth greater than 10 kHz, and shall meet the high voltage test requirements of Section 2.8.

2.4.10 The DCCT or shunt shall be located downstream of output filter capacitors, output voltage dividers, freewheeling diodes, etc. so only current flowing to the load is measured.

2.4.11 Buffered outputs from the DCCT shall be wired to an isolated connector (LEMO or BNC) mounted on the front of the power supply.

2.4.12 All power supplies that do not use analogue setpoint/feedback control shall have a control setpoint resolution better than the regulation specification, with a minimum of 12 bit control.

2.4.13 Feedback resolution shall be equivalent or better than control resolution to facilitate self-testing of the control and regulation circuitry.

2.5 Safety and Environmental

2.5.1 Materials defined as Notifiable Chemical and Biological Substances and Designated Chemical Substances according to Table 19 and 20 respectively of the appendix of the Saskatchewan Occupational Health and Safety Regulations (OHS Regs. 1996) shall not be used without written permission from CLSI. Contamination limits set out in Table 21 of the Appendix of OHS Regs 1996 shall not be exceeded in any area where a worker is usually present; see also any applicable Sub-Sections of 4 Oct 96 co-1.1 Reg 1 s307, s309, and clause 346(f).

2.5.2 Asbestos, asbestos-type insulation, and insulating or dielectric fluids containing PCBs shall not be used. Where a choice of materials is available (e.g. cables, support hardware), preference shall be given to materials or equipment exhibiting a higher level of fire resistance.

2.5.3 The power supplies shall be constructed with a view towards safety. All high voltages (greater than 30 V_{ac}) shall be barriered or compartmentalized. High voltage components, connectors, wiring terminations, etc. shall be physically separated from low voltage control circuits. Personnel should not be exposed to high voltages while performing routine service on energized control circuits.

2.5.4 A legible sign with the words "Danger--High Voltage" and "Danger--Haute Tension" in letters that are not less than 50 mm in height on a contrasting background shall be posted in a conspicuous place at every approach to live high voltage electrical equipment.

2.5.5 Every control device shall be so designed and located as to permit quick and safe operation at all times.

2.5.6 The path of access to every electrical switch, control device or meter shall be free from obstruction.

2.5.7 The power supply shall be capable of operation in an ambient temperature range of 10° C to 40° C. The normal ambient temperature of the main floor area at CLSI is 23° C. The expected temperature of the main floor will be +/- 1° K during normal operation.

2.5.8 The main CLSI building will be equipped with an overhead sprinkler system. Power supply racks or cabinets should be “weather-resistant” cabinets that are capable of withstanding modest exposure to water or other fluids.

2.5.9 The components shall be able to withstand a relative humidity range of 0 % to 90% noncondensing. The expected relative humidity limits under operation are from 25% during the winter months to 50% during the summer months.

2.5.10 Low conductivity cooling water (LCW) will be supplied by CLSI. The supply water will have a conductivity of less than 600 μS/m. The maximum water inlet temperature is 40 degrees Celsius and the minimum water inlet temperature is 10 degrees Celsius. The water temperature will be maintained within ±3 K of a temperature in this range. (Supply temperature of the LCW will normally be between 27 to 33 degrees Celsius.)

2.5.11 The Proponent shall specify the expected consumption of low conductivity water for the normal operation of the power supply as part of the proposal. The Proponent shall provide information of the expected heat loads to air and LCW for the power supply at this time and shall notify CLSI of any special cooling requirements.

2.5.12 Where water-cooling is required, the cooling system shall operate at an input pressure of 700 kPa.

2.5.13 The pressure drop to achieve the required flows in the cooling water circuits shall not exceed 300 kPa.

2.5.14 Inlet and outlet connections shall be clearly labelled.

2.5.15 Any cooling circuits should be designed so that under normal operation the velocity of the cooling water is maintained in the transition zone between laminar and turbulent flow (typically 1.5 to 2 m/sec).

2.5.16 The maximum temperature rise in the water cooling circuits should be kept below 20 K.

2.5.17 All small tubing water connections shall be American standard Swagelok fittings. All large water tubing shall use NPT threads.

2.5.18 All water flow monitoring shall be measured on the outlet side of the components being cooled. If parallel cooling circuits are used, a flow meter/flow switch must be used on the outlet of each parallel circuit.

2.6 Applicable Codes, Standards and Procedures

2.6.1 The following documents can be considered as part of this specification. All equipment shall be built in strict accordance with the following standards:

1. CSA Canadian Electrical Code 1998 C22.1-98 Safety Standards for Electrical Installations.
2. All other applicable CSA standards.
3. ANSI/IEEE Std. 519-1992 IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems
4. Industry Canada ICES-001 Industrial, Scientific and Medical Radio Frequency Generators
5. ANSI/IEEE Standard C57 Distribution, Power and Regulating Transformers.
6. NEMA Pub. No. SG 5 – 1995 Power Switchgear Assemblies.
7. Radiation Health and Safety Regulations of the Saskatchewan Occupational Health and Safety

2.6.2 Unless otherwise specified, the issue date or revision level shall be that in effect on the date of the Invitation to Quote. Exceptions to these standards shall be reviewed and accepted by CLSI.

2.7 Quality Assurance

2.7.1 The Proponent shall maintain and apply a quality assurance program compliant with ISO-9001 for the design, manufacture and testing of all components.

2.7.2 Power supplies and components shall have either one of the certification marks listed in http://www.saskpower.com/services/cecr_sk/bulletins/item14.shtml or shall be approved by a Standards Council of Canada accredited testing laboratory to SPE-1000 standard and have a corresponding sticker indicating this.

2.8 Inspection, Testing and Commissioning

2.8.1 CLSI staff shall do the installation of the power supply. Special requirements will be noted in the Power Supply Requirement Summary sheet. CLSI main hall is equipped with a 10 tonne overhead crane. The crane has coverage extending from the loading area to drop areas above the booster and storage ring shielding tunnels. This coverage does not include the entire shielding area. CLSI has a pallet jack rated for 2000 kg (4500 lb). The Proponent must advise CLSI if additional handling equipment is required.

2.8.2 The Proponent shall formulate acceptance test procedures for all components and will provide the facility and instrumentation to perform all relevant tests to ensure compliance with this specification. The acceptance test procedures shall include but not be limited to all of the testing procedures specifically outlined in this document. These test procedures are subject to CLSI review and acceptance.

2.8.3 CLSI reserves the right to have access to the Proponent's facility at any time during the fabrication and testing procedures. CLSI shall have the right to witness any manufacturing or testing procedures upon request. When requested, the Proponent shall provide a minimum of 21 days notice in advance of any test date to allow for CLSI to make the necessary travel arrangements.

2.8.4 CLSI reserves the right to require additional or more extensive tests to be conducted in the event of marginal design or performance.

2.8.5 All items purchased or manufactured by a subcontractor used in the work shall be clearly identified to CLSI in the proposal.

2.8.6 Review and acceptance of CLSI shall not release the Proponent from its responsibility to correct errors, oversights and omissions to ensure conformance to the specifications in this document.

2.8.7 Isolation testing shall be performed on all power supplies as specified in the Dielectric Voltage Withstand section of SPE1000. These tests shall be performed at 60 Hertz for a one minute duration. The actual leakage currents shall be measured and recorded. These tests include the following:

1. For equipment rated 250 V input voltage or less, 1000 V AC between the input terminals and frame (ground). For equipment rated greater than 250 V, 1000 V + two times the rated input voltage between input terminals to the frame (ground).
2. For equipment in which voltages greater than 30 V but not more than 600 V are generated, 1000 V + two times the generated voltage between the points having the generated voltage and each of the primary circuit, accessible secondary circuits, and accessible metal.
3. For equipment in which voltages higher than 600 V are generated, 1750 V plus 1.25 times the generated voltage between the points having the generated voltage and each of the primary circuit, accessible secondary circuits, and accessible metal.

Note: During the input and transformer high voltage testing all low level interlock and control circuits and the frame shall be grounded.

2.8.8 A turn-to-turn test shall be performed at 400 Hz or higher frequency on the transformer. This test shall apply or induce a primary voltage of:150% of nominal voltage for a duration of 7200 cycles of the applied frequency.

2.8.9 The power supplies shall undergo initial functional testing. This testing shall include but not be limited to the following:

1. Control functions shall be exercised through all states.
2. All interlock functions shall be checked for proper operation and indications. All fault status indicators shall latch until reset.
3. After the unit's warm up period, the regulation and reproducibility of the power supply shall be measured at a minimum of four output values spanning the power supplies working range, operating for a period of 4 hours for each value.
4. Heat checking shall be done on all critical components to insure operation within manufacturer's ratings. The Proponent shall temporarily install thermocouples on critical components and on power supply critical points. These points shall be agreed on between the Proponent and CLSI. Alternatively a calibrated infra-red imaging camera may be used for these measurements. Infra red measurements must be corrected for the emissivity of the surface being measured. A heat run shall be conducted at 110% load conditions, concluding after equilibrium temperatures have been reached.

2.8.10 Where applicable, static water tests shall be done at 1.4 MPa for a minimum of 1 hour with no indications of leaks.

2.8.11 Water cooling systems shall be tested to confirm minimum required flow rate is achieved with less than 300 kPa pressure drop.

2.8.12 Proponent shall submit certified test reports to CLSI for approval before shipping the power supplies.

2.8.13 The above tests may be waived at CLSI's discretion if a commercially available off-the-shelf power supply is used.

2.8.14 For purpose of warranty under an order for these power supplies, final acceptance of installation is defined as the successful completion of acceptance tests at CLSI to substantiate the compliance with this specification. Final Acceptance tests should be completed within three months of the delivery date. The Proponent will be notified of the test dates and may have a representative present to witness the tests. The Proponent shall be held responsible for the contracted performance of the modules produced and delivered to CLSI.

2.8.15 Final Acceptance testing shall include any or all of the following tests:

1. Tests described in sections 2.8.1, 2.8.7, and 2.8.7.
2. Connection to actual loads and verification of conformance to specifications.

2.9 Reliability and Maintainability

2.9.1 The power supply shall have a warranty of at least one year after final acceptance.

2.9.2 The power supply shall be designed and constructed for an expected operational lifetime of greater than 20 years. It is understood that maintenance may be required during this period. Subassemblies should be designed for repair rather than replacement.

2.9.3 Power supplies shall be designed and constructed to be in continuous use with only limited maintenance periods throughout the year. Major maintenance periods will be scheduled twice a year and have a duration of approximately 10 working days. Weekly maintenance periods will likely be scheduled to last for one 8 hour time period. Weekly maintenance should not be required. All power supplies shall have a minimum mean time between failure of 40,000 hours in the operational environment at CLSI as outlined in this specification.

2.9.4 The power supply shall be designed and constructed in such a way as to supply access to any system components that are expected to fail in the normal operating environment. Large assemblies that need to be removed from cabinets or racks for service should be mounted on slides. Safe and easy access to all external connection points must be incorporated into the overall design. Easy access shall be made available to all components, especially solid state power components, fuses, and printed circuit boards. All components shall be removable without cutting or removing cabinet frame members. The Proponents drawings shall show the positions of the major components in the power supply.

2.9.5 In general, the power supply can be set up and operated according to standard industrial practices. However, maintenance and testing in some cases may be expedited by deviating from standard practices, provided extra precautions are taken to reduce hazards to an acceptable level before these deviations are permitted. If applicable, these precautions must be clearly documented in the manuals.

2.9.6 The Proponent shall supply a list of recommended spare parts along with cost information.

2.9.7 Different coloured wires shall be used wherever possible to facilitate troubleshooting.

2.9.8 Each cable and wire shall be identified using mechanically printed heat shrink markers at each end. These shall be keyed to identical numbers used on electrical schematics.

2.9.9 All threaded mechanical fasteners should be American Standard Thread. The use of metric standards is negotiable with CLSI. If metric standards are used, spare nuts and bolts shall be provided by the Proponent.

2.10 Layout

2.10.1 All equipment shall be housed in a suitable enclosure to prevent contact with hazardous voltage or current by personnel. These enclosures may be one of the following:

1. 19” rack mount chassis

   Rack mount chassis should be constructed so that it is impossible to touch high voltage/high current connections from the outside with a thin conductor of reasonable length. These cabinets must provide protection for uninformed personnel and be suitable for unattended operation. Doors and removable panels shall be fitted with redundant and independent interlocks if they provide access to high voltage or high current potentials.

   The Proponent shall provide the corresponding racks, rails, side panels, doors, tops, and blank panels required to make a complete enclosure.

   No elements of the rack should extend above a height of 2.1 m from the floor height.
2. Permanent completely enclosed cabinets

   Permanent cabinets should be constructed of metal panels with plastic or safety glass for windows when necessary. They should be constructed so that it is impossible to touch high

voltage/high current connections from the outside with a thin conductor of reasonable length. These cabinets must provide protection for uninformed personnel and be suitable for unattended operation.
Doors and removable panels shall be fitted with redundant and independent interlocks. Where practical cabinets should include interior lighting activated when doors or panels are opened.
No elements of the cabinet should extend above a height of 2.1 m from the floor height.

3. Permanent walk-in enclosures

Walk-in enclosures may be used for equipment that occupies large areas.
Access doors and panels shall be fitted with redundant and independent interlocks. Local control is required from outside the enclosure. Enclosures shall provide protection for uninformed personnel and be suitable for unattended operation.
Walk in enclosures shall include interior lighting activated when doors or panels are opened. The interior of walk in enclosures shall be a minimum of 2 m high. Overall dimensions and construction of walk in enclosures are subject to review and acceptance by CLSI
Walk-in enclosures shall be equipped with grounding hooks to allow for the safe discharge of high voltage on devices that may retain a charge. These grounding hooks should be positioned to prevent entrance without the hooks being moved.

2.10.2 Racks, cabinets, and enclosures shall have lifting eyes on the top for handling by a crane.

2.10.3 Racks, cabinets, and enclosures shall be constructed with a 0.1 m (4 inch) high I-beam or similar support to hold the unit off the ground and facilitate handling by a fork lift.

2.10.4 The total mass of any one component should be less than 2000 kilograms.

2.10.5 Water supply and return connections should be made through the back of the power supply near the bottom.

2.10.6 Incoming and outgoing terminals shall be located at the rear of the unit. Enclosures should be designed to accommodate top entrance of electrical conductors.

2.10.7 Incoming AC terminals shall be clearly marked with voltage and phase (if applicable). DC output terminals shall be clearly marked with channel number and polarity.

2.10.8 Two safety ground connection points shall be located at opposite ends of the back of the enclosure. An additional grounding point shall be provided near the incoming AC terminals.

2.11 Other Requirements and Constraints

2.11.1 All labelling, manuals, and other documentation shall be in English.

2.11.2 The Proponent shall supply complete documentation of all components and subsystems. Hardcopies (4) and electronic copies (including editable source files) of all documentation shall be provided.

2.11.3 All documentation should conform to the “Vendor Documentation Specification” (CLSI 0.4.1.1 Rev. 3).This documentation shall include but be not limited to the following:

1. Users/operation/maintenance manuals, which shall contain, but not be limited to: specifications, operating instructions, control system interface commands/protocols, hook-up instructions, circuit diagrams, block diagrams, maintenance procedures (both operational and preventative), component data sheets, normal adjustments and calibration setup procedures.
2. A final parts list along with a list of recommended spare parts and their cost information.
3. A complete set of electrical and mechanical drawings shall be supplied for each power supply.

2.11.4 The Proponent shall provide CLSI with electronic copies of all custom developed source code, PLC programs and embedded logic in source and binary format on CD-ROM.

2.11.5 All test measurement results shall be provided in hardcopy, on CD-ROM, and archived at the Proponent’s location for at least the duration of the warranty.

2.11.6 All power supplies shall have a stainless steel or aluminium nameplate on each unit that shall include the following information:

- CLSI Equipment Tag number (Details to be worked out with CLSI)
- Manufacturer's name and address
- Power supply type and serial number
- Input voltage and current ratings
- Output voltage and current ratings
- Gross weight of the unit
- Date of manufacture
- Cooling requirements (if required)
  - Flow Rate (l/m)
  - Pressure drop (kPa)
  - Maximum Temperature Rise (K)

2.11.7 The nameplate information should be in 14 point size fonts.

2.11.8 All shipping containers shall be marked or tagged with the following information:

- CLSI purchase order number.
- Shipping address as specified within the contract.
- Proponent's name.
- Components contained within each package.
- "Top-side up" if required.
- "Fragile" if required.
- Shock and Tip sensors on containers are encouraged.

2.11.9 Where possible shipping should be by air cushion truck. Shipping by rail or flatbed truck is discouraged.

2.11.10 Proponent shall notify CLSI ten (10) days prior to shipment. The notice shall include a list of equipment, origin, shipping date, shipping firm, routing of shipment, anticipated date of arrival, and shipping weight. CLSI reserves the right to approve shipping firm and route.

3. REFERENCES

1. "Control System Technical Specification" 7.4.39.1 Rev. 2
2. "Vendor Documentation Specification" 0.4.1.1 Rev. 1.
3. CSA Canadian Electrical Code 1998 C22.1-98 Safety Standards for Electrical Installations.
4. ANSI/IEEE Std. 519-1992 IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems
5. ANSI/IEEE Standard C57 Distribution, Power and Regulating Transformers.
6. NEMA Pub. No. SG 5 – 1995 Power Switchgear Assemblies.
7. Radiation Health and Safety Regulations of the Saskatchewan Occupational Health and Safety
8. Saskatchewan Occupational Health and Safety Regulations (OHS Regs. 1996)
9. "Vibration Isolation Mechanical Equipment", BKL report
10. SPE-1000-99 "Model code for the Field Evaluation of Electrical Equipment" CSA International.

3.1 Sample Power Supply Requirements Summary

Power Supply Requirement Summary	
Application:	
Type (Unipolar, Bipolar, Four Quadrant)	
Physical Arrangement	
Number of groups of supplies	
Number of channels/group	
Total number of output channels	
Output Voltage Range (V)	
Output Current Range (A)	
Regulation	
Bandwidth	
Full Range	
Small Signal	
Control	
Load	
Nominal load resistance (Ω)	
Nominal load inductance (H)	
Output cable size	
Special Requirements	

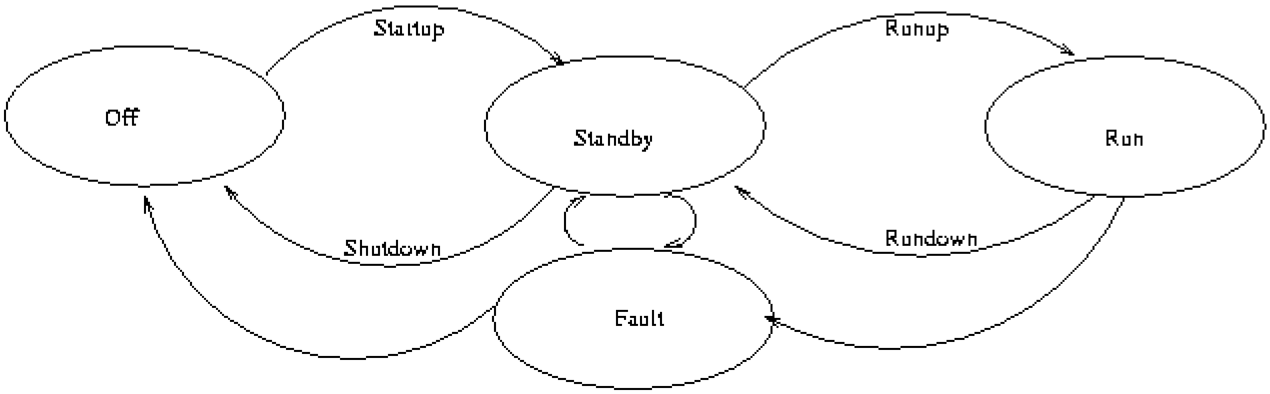
3.2 Proponent Data Sheet

A Proponent Data Sheet for each power supply, characterizing the configuration of the power supply, shall be provided by the Proponent as part of the proposal. It is intended that the Proponent Data Sheets become part of this specification for the purpose of fabrication and testing. Deviations from the Proponent Data Sheets submitted with the proposal shall be subject to review and acceptance by CLSI.

Proponent Data Sheet	
Application	
Type (Unipolar, Bipolar, Four Quadrant)	
Physical Arrangement (describe)	
Size	
Width	
Depth	
Height	
Weight	
Terminal Connections	
Output Voltage Range (V)	
Output Current Range (V)	
Output Regulation	
Vs Line	
Vs Load	
Vs Time	
Vs Temp	
Ripple	
All Factors Combined	
Output Bandwidth	
Full Range	
Small Signal	
Control system interface/protocol (describe)	
Number and type of interlocks (list)	
Local front panel metering and indicators	
Input Voltage	
Number of phases	

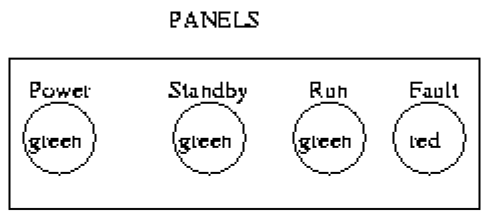
Maximum Output Power	
Maximum Input Power (kVA)	
Minimum efficiency for all output levels >80% rated output power	
Efficiency at 90% rated output current	
Minimum power factor for all outputs >80% rated output power	
Water Cooling Requirements	
ΔT (K)	
ΔP (kPa)	
Q (l/s)	
Heat to ambient air (W)	
Major Components (Manufacturer, Type, Rating/Specifications)	
Input Breaker	
Contactor	
Transformer	
Insulation Class	
Operating Temperature	
KVA	
Filter Choke	
Insulation Class	
Operating Temperature	
KVA	
Inductance	
Filter Capacitors	
Ripple Current	
Temperature	
Capacitance	
Power Semiconductors(s) including type, number, and configuration	
DCCT (or other current regulation sensing element)	
Warranty	

3.3 CLSI Control System Reference State Machine



LED States

State:	Power	Standby	Run	Fault
Off	On	Off	Off	Off
Startup	On	Flash	Off	Off
Standby	On	On	Off	Off
Runup	On	On	Flash	Off
Run	On	Off	On	Off
Rundown	On	Flash	On	Off
Shutdown	Flash	Off	Off	Off
Fault	On	Off	Off	On



Draft Copy: Glen Wright, March 13/2001

3.4 Power Supply Requirements Summary

Power Supply Requirement Summary	
Application: Room 2406, PS2406-08	
Type (Unipolar, Bipolar, Four Quadrant)	Unipolar
Physical Arrangement	
Number of groups of supplies	1
Number of channels/group	3
Total number of output channels	3
Output Voltage Range (V)	20
Output Current Range (A)	135
Regulation	+/- 25 ppm, peak-to-peak, over 8hrs
Bandwidth	
Full Range	DC
Small Signal	
Control	Serial RS232/485
Load	
Nominal load resistance (Ω)	0.054-0.078
Nominal load inductance (H)	0.012-0.021
Output cable size	2C #2 AWG 1000V Teck Cable per channel
Special Requirements	208 V/ 3phase / 60Hz Standalone power supply. Prefer water cooling. Physical footprint of overall power supply shall be limited to 150cm x 150 cm.

REVISION HISTORY

Revision.	Date	Description	By
A	1999-09-30	Draft	Neil G. Johnson
0	1999-10-25	Issued	Neil G. Johnson
1	2001-06-27	Additional power supply requirements. Major revision for use in procurement.	Neil G. Johnson
1A	2006-03-23	General updates	Neil G. Johnson
1B	2006-03-31	Incorporated comments	Neil G. Johnson
2	2006-04-03	Issued for Use	Neil G. Johnson
2A	2006-05-06	Updates to reduce NFPA 70E hazard classification	Neil G. Johnson
2B	2008-06-19	Updates to clarify 480 V and room requirements	Neil G. Johnson
3	2008-06-23	Issued for RFP	Neil G. Johnson
3A	2011-10-19	Updated PS Summary for RFP	D. Bertwistle
4	2011-10-31	Issued for Use	D. Bertwistle
4A	2011-12-20	Updated power supply current values.	D. Bertwistle
5	2011-12-21	Issued for use	D. Bertwistle