Science and Technology Facilities Council

ISIS

ISIS Neutron and Muon Facility

RIKEN-RAL Refurbishment Project

# UK SBS PR20005

# SEPARATOR POWER SUPPLIES SPECIFICATION

# 1 Contents

# 2 Introduction

ISIS Neutron and Muon Source is based at the STFC Rutherford Appleton Laboratory in Oxfordshire and is a world-leading centre for research in the physical and life sciences. It is owned and operated by the Science and Technology Facilities Council.

ISIS Neutron and Muon Source produces beams of neutrons and muons that allow scientists to study materials at the atomic level using a suite of instruments, often described as 'super-microscopes'. It supports a national and international community of more than 2000 scientists who use neutrons and muons for research in physics, chemistry, materials science, geology, engineering, and biology.

The RIKEN-RAL muon instruments have been in operation at ISIS for 25 years, and a major refurbishment projected is planned to replace old and obsolete equipment.

This specification provides detailed information for the requirement of HV DC power supplies to be installed and operated on the RIKEN-RAL beamlines.

# 3 Scope

This requirement is concerned with the design, manufacture, testing, documentation, and delivery of 3 Pairs of Power Supplies (6 units in total), 3 positive and 3 negative with respect to ground, each capable of a DC output of 150 KV, 3mA.

# 4 General

This document describes the requirement for six HV DC power supplies, used to charge three pairs of electrostatic plates in opposite polarity, for the separators on the RIKEN-RAL muon facility at ISIS.

Requirements summary:

- Unipolar, 3 positive and 3 negative power supply units.
- DC output at ±150 kV and 3 mA.
- Fed from a nominal AC, 230 $V_{RMS}$, single phase, 50 Hz sinusoidal supply.
- Incorporated protection and control systems.
- Operating in pairs to drive each electrostatic separator.
- Intrinsically safe design.
- High efficiency.
- High reliability and maintainability.
- Compliant with relevant standards.

# 5 Electrical Requirements

## 5.1 AC Input

The AC input will be single phase, 3-Wire, sinusoidal waveform (BS EN 50160):

- Input RMS (ph-n) voltage ..... 230 V, +10%-6%
- Operating frequency ..... 50 Hz, ±1 Hz
- THD (including all harmonics up to the order 40) ..... 5%

The AC Input will be fed through a lockable isolator for safety. The isolator is out-of-scope of this tender. The power supplies must be able to tolerate operation of the isolator, including when removing the electrical supply (including when at full rated output).

### 5.1.1 AC Input connector

The input to each power supply will be hardwired or use a standard connector that latches in position (such as powerCON 20A).

### 5.1.2 Power Quality

Electromagnetic Interference (EMI) filters will be fitted across the main input lines, to attenuate conducted EM noise, if required to meet standard BS EN 61000.

The input harmonic currents must be reduced to maintain the THD of the current drawn from the main input to less than 5% including all harmonics up to the order 40, as recommended in IEEE STD 519-2014.

The Power Factor (PF) as seen at the main input will be greater than 0.9 for all operational conditions.

Surge protection and inrush current limiting shall be employed.

## 5.2 DC Output

Each supply will be unipolar, either positive or negative with respect to ground. Three of each type are required.

- Minimum continuous rating DC output voltage ..... 150 kV
- Minimum continuous rating DC output current ..... 3 mA
- Output voltage stability (over full operational range) over 8 hours ..... 0.5%
- Maximum output voltage ripple RMS on designated load ..... 0.1% @150 kV
- Output voltage operational range ..... 10-100%
- Voltage setting resolution ..... 0.1%
- Voltage set level range ..... 0% to 100%
- Efficiency at full rated output ..... 90% or greater

### 5.2.1 Load

The designated load on each power supply is one side of a pair of electrostatic plates and the connection system. The plates are charged in opposite polarity by the power supplies specified here.

The plates can be simulated as a capacitance to the ground of the containing vacuum vessel, in parallel with a capacitance to either a virtual ground between the two plates or to the opposite plate, depending on the charge on each plate. The total capacitance will be approximately 980.5 pF (62.5 pF at the plate assembly plus 918 pF in the cable). The plates will be in a vacuum and the fault current can potentially be high. Field emission will cause small currents to flow through the circuit in normal operation, non-fault conditions.

The cable will be a specialist high voltage cable (likely to be Essex X-Ray C2236 at 102 pF/m), approximately 9 metres in length.

The cable connector to the electrostatic plates, through the vacuum vessel, will be an R24 connector.

### 5.2.2 Output connector

The output connector will be an R24 receptacle (female) suitable to mate with the R24 connector on the cable.

### 5.2.3 Output protection

Each power supply will monitor the output for arc detection. The output will be disabled upon detection of a single arc, to distinguish the arc, and reset to demand voltage immediately.

Upon detection of multiple, repetitive arcs, the power supply will stop operation, generate an alarm and require a manual reset action.

Each power supply will also include protection against total voltage reversal, overvoltage and overcurrent as a minimum.

### 5.2.4 DC Output Option

Preferably, each power supply will be capable of providing voltage in either polarity. This is to enable the use of any power supply as a spare in any position.

Desirable Option 1: The DC Output may be bipolar, in that it can operate at positive and negative rated voltage and the output is changed via a manual software command.

Desirable Option 2: The DC Output may be floating, where physical connection to a ground point dictates the polarity. The output terminal connection will be moved accordingly. A change in polarity may require physical alterations such as replacing a PCB, setting dip switches or moving internal connections.

Where a supplier can offer both unipolar, plus a bipolar or a floating differential output option, please answer the optional technical questions regarding Desirable Options.

## 5.3 Electrical safety and compatibility

### 5.3.1 Protective Earth

There will be a single terminal to which a protective earth cable can be connected. The size of earth cable will be agreed with STFC, and required to withstand a controlled energy dump, to discharge any energy storage devices, without damage to the cable.

All accessible conductive parts that have the potential to assume a hazardous voltage, only in the event of a single fault, will be connected to the main protective earth terminal, including those parts accessible during maintenance. The earth cable will be sufficiently sized to withstand maximum conceivable fault currents, and provide a path to the earth point with a resistance of less than 0.1Ω.

The power supply will protect itself from a short to earth. Preferably earth leakage will be monitored, and upon detection of significant leakage current to earth, the power supply will stop operation, generate an alarm and require a manual reset action. Preferably, the earth leakage trip level will be user settable.

### 5.3.2 Insulation and galvanic isolation

The AC input, DC output, earth terminal, control terminals and monitoring points will be galvanic isolated.

For LV circuits, the insulation dielectric strength will comply with BS EN 61975:2010+A1:2017 as a minimum. The clearance (jump) and creepage distances, present between all live LV and exposed components and any earthed panels, will comply with BS EN 60950-1 and/or BS EN 60664-1 at Pollution Degree 3.

For LV and HV circuits, the insulation shall be demonstrated by the supplier using the following test:

- Between DC output circuit and ground/earth.....165 kV DC, for 60 seconds
- Between AC, single-Phase, 230$V_{rms,}$ circuit and frame .....3 $kV_{rms}$ AC at 50 Hz for 60 seconds

### 5.3.3 Wound components

All wound components shall be suitably rated for the advised use, and shall not be operated above Class 150 (Class B).

### 5.3.4 Electromagnetic compatibility

The equipment will be designed and tested to meet, as a minimum, the following:-

- Radiated Emissions (BS EN 55011) or equivalent
- Conducted Emissions (BS EN 55011) or equivalent
- Electrostatic Discharge (BS EN 61000-4-2) or equivalent
- Radiated RF Immunity (BS EN 61000-4-3) or equivalent
- Fast transient burst (BS EN 61000-4-4) or equivalent
- Conducted RF immunity (BS EN 61000-4-6) or equivalent

# 6 Physical requirements

## 6.1 Installation

All fixings are to be metric.

The PSUs will preferably be rack mountable in 19” cabinets or equivalent. There will be at least two units in each cabinet (one positive and one negative). The cabinet is out of scope of this tender. Where the PSU is not rack mountable, it shall be supplied in a stand-alone, floor standing cabinet.

There will be a maximum of three cabinets. Each cabinet, equipment and connections shall fit in a space of:

- For top mounted DC output connector ..... 660 mm wide, 800 mm deep and 2000 mm high
- For rear mounted DC output connector .... 660 mm wide, 1200 mm deep and 2000 mm high

The cabinet will have feet that allow manoeuvring by pallet truck and/or lifting points to allow the use of an overhead crane. Lifting points must be suitably rated for the total load and compliant with LOLER regulations.

### 6.1.1 Connections

The AC input connection shall be on the rear or bottom of the unit.

The DC output connections shall be on the rear or top of the unit.

The earth connection shall be on the rear of the unit.

The remote control, external interlock and user monitoring point connectors shall be on the rear or front of the unit.

The local user interface shall be on the front of the unit.

## 6.2 Safety

All live parts shall be enclosed to a minimum of IP2X as described in standard IEC 60529. As a minimum, a specialist tool must be needed to remove any cover that would reveal a potentially live part, such as torx or tamperproof allen key. Slotted, pozi, Phillips and hex head tools are not acceptable.

Consideration shall be given to how the PSU will be moved. Where it is expected for people to lift, carry or hold the PSU; then the PSU shall weigh no more than 50 kg, and suitable carry handles provided.

### 6.2.1 Warning and information labels

Each power supply enclosure will have warning labels on all external covers that conceal potentially live components. The labels will comply with ISO 3864-2 or equivalent and comprise the following:

- Triangular warning (flash sign) labels
- Voltage warning labels indicating nominal voltage values
- Text in International English
- Waiting times following voltage interruption for compartments concealing stored energy components

Identification labels will be permanently attached to each power supply. Information will include, as a minimum:

- Serial number
- Equipment type
- Weight
- Input and output ratings

### 6.2.2 Risk assessment

Safety is of paramount importance at all stages of the equipment lifecycle and a rigorous demonstration of safety is required by the STFC. The safety demonstration shall include a risk assessment that considers, as a minimum:

- Identification and resolution of hazards inherent to the design of the power supplies.
- Interference with other electrical/electronic systems or networks.
- Software dependent safety functions.

## 6.3 Environment

The PSU will provide air cooling to control the temperature of components to within manufacturers' datasheet specified limits. Where the PSU is supplied in a cabinet, air flow shall be managed.

Maximum ambient temperature .....+40 °C

Maximum daily average temperature .....+35 °C

Minimum ambient temperature.....0 °C

Storage temperature..... -5 °C, + 40 °C

Mean relative humidity..... ≤ 75%

Maximum relative humidity..... ≤ 90%, non-condensing

Sealing level for ventilated areas..... IP2X (IEC 60529)

Audible noise (at any operating output)..... Less than 75 dBA @ 1 metre

Cooling .....Forced or natural air

### 6.3.1 Fans

When forced air cooling is used, it is desirable to include an element of redundancy. All fans shall be a sealed ball bearing type with a minimum design life expectancy of 20,000 hours, and electrically supplied and protected within each power supply enclosure by the AC input.

The following will be agreed at design review:

- Location of the inlets and outlets of forced air.
- Cooling fan redundancy.
- Use of filters.
- Maintenance and inspection intervals.

# 7 Control

Each power supply shall provide, as a minimum:

- Closed loop control of the output voltage.
- Local and remote control, monitoring, alarms and status information.
- A fail-safe method of reducing the output to zero on the loss on any interlock input.
- Condition monitoring and system protection.

## 7.1 Local user interface

The local user interface shall provide, as a minimum:

- Display of output voltage and current, preferably as analogue dials.
- Control of output voltage demand, and preferably control of output voltage rate of rise.
- Control of output current limit.
- Status indication including AC input power on, DC output on, alarm status, arc detection status, remote/local mode indicator.
- Remote/Local control mode selectable on the front panel (in addition to this feature being available remotely)
- DC Output On and Off commands via push-buttons.
- Alarm/Interlock Reset command via a push-button.

## 7.2 Protection

The control system shall monitor and protect the power supply from hazardous or detrimental conditions (i.e. faults). Consideration shall be given to how a pair of power supplies will function together when driving a single load. This shall include, as a minimum:

- Overcurrent protection of the AC input.
- Monitoring of the AC input for protection of the power supply.
- Overcurrent, over voltage, short circuit, arc protection of the DC output.
- Over temperature protection of internal components.
- External interlock handling.
- User input and communication error handling.

The action of the controller following the detection of a fault will depend on the resultant risk to equipment and people. For example, earth leakage will result in a latched inhibit requiring a manual reset command; single arc detection may be able to safely re-enable the DC output after the fault has cleared; and the DC output voltage rate of rise may be limited to prevent overcurrent rather than cause a trip. Protection and actions will be agreed upon at a design review.

In all cases, an alarm will be generated to warn the user of the fault that has occurred, on both the local user interface and remote control system. The fault will be logged by the power supply controller and information will remain accessible even after the fault and alarm have cleared.

Where one power supply of a pair driving a single load (that is, one positive and one negative) detects a fault. The second power supply must also react appropriately to prevent hazardous or detrimental conditions.

## 7.3 Hardwired inputs and output

### 7.3.1 External interlocks

Each power supply shall have a minimum of 1 external interlock. When the interlock is not complete:

- The power supply will switch off the DC output.
- The interlock will be latched until the local Reset button is manually pressed, or a Reset command is sent from the remote controller.
- An alarm will be generated, which can be read via the remote controller, and is displayed on the local user interface.

Each interlock shall be independently capable of switching the DC output off, and designed to be fail-safe. Preferably, the interlock will be hardwired from input to output, with programmable electronics used only for monitoring of the interlock.

Each interlock input shall have two terminals on the power supply connection. The first terminal will be for a control output voltage, preferably 24 V and no greater than 48V, which will be switched via an external volt-free relay contact in the ISIS control system, and returned to the second terminal. The control output voltage must be present at the return terminal for the interlock to be complete.

### 7.3.2 PSU Ready and On signals

Each power supply will provide a minimum of two volt-free contacts to indicate the status of the power supply and output.

The first, called the PSU Ready signal, will make (close) the contact when the power supply is able to energise the DC output. This signal is used to provide a warning light at the separator to warn that there is potential for high voltage.

The second, called the PSU ON signal, will make (close) the contact when the DC output is on and stable. This signal is used as part of a chain to indicate that the muon facility is ready for use.

The volt-free contacts will be supplied by the ISIS control system at 24 V and less than 1 A.

If this requirement cannot be met by the supplier, then an alternative solution must be offered and agreed with STFC at the first design review.

## 7.4 Remote control and communications

The power supplies will be remotely controllable, via a communications interface.

### 7.4.1 Command list

A list of available commands and examples shall be provided at a design review. Available commands will include, as a minimum:

- DC Output On command
- DC Output Off command
- Output voltage demand, and preferably output voltage rate of rise
- Output voltage and current read back
- Alarm/Interlock Reset
- Power Supply status information (e.g. PSU is on, off or in alarm)
- Alarm information

### 7.4.2 Communication standard

The communications interface will meet a recognised standard and common protocol.

By preference, RS-232 should be utilised, otherwise RS-485, RS-422 or Ethernet (IEEE 802.3-2018) is acceptable. USB is not acceptable.

If RS-232 is to be used, the port must be capable of reliable communications over 15 meters of cable. A voltage of ±15V shall be utilised, with a minimum of 20 mA source current capacity. TTL levels are not acceptable.

If Ethernet (IEEE 802.3-2018) is to be used, it must be compatible with IP4 addressing and assignment from a DHCP server, and be invulnerable to cyber attacks.

### 7.4.3 Communication protocol

By preference, the commands will be human-readable, in ASCII characters, terminated by a special character such as Carriage Return-Line Feed.

The power supply controller will respond to every command, regardless of the validity of the command. For example, a command that does not request information will return a message such as “OK”; an invalid command will return a message such as “error”.

The power supply controller will not send unsolicited messages in normal operation. Any information sent on start-up will be available by request.

# 8 Testing

The completed power supplies will be tested at both the manufacturer's site and after installation at RAL. The satisfactory completion of both of these tests shall be contractual milestones.

## 8.1 Site acceptance test

After delivery to RAL, the power supplies will be tested by STFC to ensure that no damage or performance degradation has occurred during transport and delivery.

The SAT schedule will be agreed upon after the successful completion of the manufacturer's tests. As a minimum, it will include an 8 hour rated voltage test while connected to a suitable load, and a check of the remote control and external interlocks.

The test dates will be coordinated with ISIS shutdown dates.

# 9 Design Reviews

The supplier will arrange design reviews with the Lead Engineer at STFC. The following review schedule will be followed:

- Supplier technical specification (in response to this document), including:
  - Information on fans
  - The power supply protection system
  - PSU Ready and PSU On signals
  - Remote control command list
- Interface drawings (mechanical and electrical), including dimensions.
- Equipment layout and assembly diagrams, including dimensions.
- Type test specification.
- Routine test specification.
- First article inspection.
- Documentation (please see Section 11).

Following a design review, the project/design shall not proceed until that stage of the design reviews is approved by the Lead Engineer at STFC. The supplier shall allow at least two weeks for STFC staff to review documentation and drawings before providing feedback to the supplier.

The approval of the detailed design by the STFC in any design review shall not relieve the supplier of any responsibility for meeting the final specifications of the contract.

# 10 Spare parts

During the acceptance phase of the project, the supplier shall provide STFC with a written detailed list of suggested spares. Once agreed upon, these may be purchased by STFC as part of the contract. This list should, as a minimum, include all magnetic wound components, power semiconductors and any manufacturer specific control printed circuit boards.

# 11 Project management

The supplier shall propose a project plan. This will include a design review schedule and the manufacturer's test schedule. Complete delivery to site must be within 16 weeks of receipt of order.

STFC will nominate a Lead Engineer who will act on its behalf and be responsible for all official communications with the supplier. The supplier shall name a Project Manager and Lead Engineer who shall direct the design, manufacture, testing and delivery of the power supplies. Regular contact between the project team is expected.

# 12 Training

Where required and agreed with STFC the supplier is to provide comprehensive training concerning the power and control circuits, operation, configuration and maintenance of the power supplies.

# 13 Documentation and drawings

All documentation and drawings shall be provided as electronic copies in International English. For hard copies, the documentation shall be in A4 or a specific format requested by the STFC Lead Engineer. All drawings shall be in the "*.dwg" format.

All documentation and drawings shall become the property of the STFC and will comprise the following:

- Power supply technical specification.
- Routine test specification.
- EMC report.
- Mechanical and Electrical interface drawings.
- Power and control schematics.
- Control block diagram.
- Power and control wiring drawings.
- Detailed assembly diagram.
- Bill of materials to board level.
- Operations manual, comprising of at least:
    - Installation and wiring guidelines.
    - Configuration and set-up procedures.
    - Interface display and control description.
    - A list of alarms.
    - A list of monitored parameters and their critical values.
    - Fault management description.
    - Fault response description (i.e. the operator's response and behaviour to a fault).
    - Corrective maintenance and preventive maintenance document (Maintenance manual).
    - Calibration procedure (if required).
    - Reference to wiring diagrams
    - Circuit diagrams of all control modules and circuit boards showing all component values and device types.
    - Circuit operational descriptions with drawings/sketches etc. as necessary to allow maintenance technicians/engineers to rapidly understand the function of circuits to component level.
    - The remote command set and the communication settings including the serial port pinouts.
- Spare parts list and recommended quantities for a minimum 20 year operational life.
- Special tools list (if required).

- The Intellectual Property rights will remain with the manufacturer and will not be disclosed by STFC to third parties.

# 14 Delivery

Complete delivery to site must be within 16 weeks of receipt of Purchase Order.

Delivery Address: STFC Goods inbound
Rutherford Appleton Laboratory
Didcot
Oxfordshire
OX11 0QX

All packaging, insurance and shipping costs in delivering to RAL shall be made entirely at the expense of the supplier. The supplier shall ensure proper protection of the power supplies against any damage from severe environment conditions, handling or transportation while delivering to RAL.

The total weight of each package shall be clearly displayed on the outside.

Delivery of the power supplies and other items to RAL shall be to an agreed schedule. The delivery of the power supplies shall be made during the STFC working hours and following a minimum of 3 days' prior notice.

If delivery notice is not provided or is attempted outside the above hours, STFC reserves the right to refuse delivery. Any increase in delivery charges due to a refused delivery will be incurred by the supplier.

# 15 Warranty

The supplier shall provide a minimum warranty period of twenty-four months, independently covering each power supply and components, for all faults related to defective parts or manufacturing processes. This period shall start after the commencement of power supply operational life.

# 16 Abbreviations

RAL – Rutherford Appleton Laboratory. Client site.

STFC – Science and Technology Facilities Council. Sponsoring council.

HV – High Voltage

PSU – Power Supply Unit

THD – Total Harmonic Distortion

LOLER – Lifting Operations and Lifting Equipment

EMI – Electromagnetic interference

EMC – Electromagnetic compatibility

PF – Power Factor

END OF SPECIFICATION