TECHNICAL SPECIFICATION

SPECIFICATION FOR A 16 kA/300 kW

PULSED DC POWER SUPPLY FOR MAGNET TESTS

P. Bossard
TABLE OF CONTENTS

1. Introduction
   1.1 General remarks 3
   1.2 Type of power supply (Variants A, B, C) 3
   1.3 Delivery 4
   1.4 Acceptance tests; guarantee 4
   1.5 Technical information 5

2. Table of Parameters 6

3. Aspects concerning the design of the supply
   3.1 Versatility 8
   3.2 Power part 8
   3.3 Timing control and interlocks 10
   3.4 Voltage and current control; ripple 11

4. Appendix
   I. Basic diagrams
   II. Questionnaire
1. Introduction

1.1 General remarks

In order to test various types of electromagnets and the so-called septum magnets in particular, a power supply is required, as specified in the following.

This specification must not be considered as complete and rigid, CERN is on the contrary prepared to examine any suitable proposal made by tendering firms. Proposals may be derived from existing models, in order to gain in experience, development costs and time for delivery.

The decision will be based upon technical performance (main parameters, versatility and operational safety), price and time for delivery. A Parameter questionnaire is given at the end of the specification, and further copies are annexed to the tendering documents.

1.2 Type of power supply (Variants A, B, C)

Tenders are asked for three different types:

- **Variant A** (economy type). This is the simplest possible version, providing full output power, but without filter and current regulator. Although it would be for limited use, mainly magnet power test runs, it is asked with regard to price and short time for delivery.

- **Variant B** (universal type). This version is intended for the same power ratings, but with low voltage ripple and stabilized current. It could be used for complete magnet tests, including magnetic field measurements.

- **Variant C** (combined type) It is hopefully expected to obtain short terms for delivery of a basic unit, with provision to add filter and regulator devices at a later time. In the end it should respond to
the same specification as Variant B.

1.3 Delivery

It is understood that the contractor shall deliver one power supply type A, B or C, completely ready for immediate service at CERN.

Safe delivery by road shall be entirely left to the responsibility of the supplier.

CERN is very much interested in a short time for delivery, as follows (after date of order, until formal provisional acceptance at CERN):

- 4 to 6 months for Variant A
- 8 months for Variant B
- 6 months for Variant C, basic unit; filter and regulator to be added at a later time.

1.4 Acceptance tests; guarantee

Prior to delivery, the manufacturer must perform a series of tests in the presence of a representative of CERN. All equipment required for this test, i.e. a dummy load, measuring instruments etc. must be supplied by the manufacturer.

After delivery a representative of the supplier must start up the power supply under his responsibility and perform one more series of tests for the formal provisional acceptance at CERN. All measuring equipment and the installation work required for this test will be provided by CERN.

The manufacturer is entirely responsible for a faultless design and manufacture of the power supply and must guarantee for a period of one year against any defects due to faulty material, design or workmanship.

PS/7328
1.5 Technical information and access to the factory

It is demanded that CERN should be informed about all technical details of the design and of any subcontracting. The contractor solely shall be responsible to CERN in the case of subcontracting.

The manufacturer must submit one set of drawings for approval before production is started, and supply after delivery one complete set of final drawings and an operation instruction manual.

Furthermore, the contractor must immediately after the order submit a time schedule of manufacture, followed by monthly progress reports.

CERN also demands the right of access to the works of the contractor and of any subcontractor during the production period, and to have a representative present during the provisional acceptance test.
### 2. Table of Parameters

**POWER RATINGS** *(Variants A, B, C)*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nom. voltage</td>
<td>50 (100) V DC</td>
</tr>
<tr>
<td>Nom. current</td>
<td>6 (3) kA DC</td>
</tr>
<tr>
<td>Rectifier</td>
<td>300 kW DC</td>
</tr>
<tr>
<td>Mains voltage</td>
<td>3x380 V AC, 50 Hz</td>
</tr>
<tr>
<td>Air temp.</td>
<td>10 - 40°C</td>
</tr>
<tr>
<td>Cooling water temp.</td>
<td>10 - 30°C</td>
</tr>
<tr>
<td>Voltage range</td>
<td>10 ranges (transformer steps) for 4, 6, 8, 10, 13, 18, 23, 30, 38, 50 V of each range</td>
</tr>
<tr>
<td>Voltage adjust</td>
<td>10 - 100%</td>
</tr>
<tr>
<td>Voltage resolution</td>
<td>≤ 1 • 10⁻³</td>
</tr>
<tr>
<td>Current range</td>
<td>2 ranges (continuous and pulsed) at any of the 10 voltage ranges</td>
</tr>
<tr>
<td>Continuous mode</td>
<td>0.6 ≤ 6 kA DC</td>
</tr>
<tr>
<td>Pulsed mode</td>
<td>0.8 ≤ 16 kA DC</td>
</tr>
<tr>
<td>Pulse length</td>
<td>0.1 ≤ 1 sec</td>
</tr>
<tr>
<td>Cycle time</td>
<td>1 ≤ 10 sec</td>
</tr>
<tr>
<td>Duty cycle</td>
<td>t/T ≤ 0.1 ≤ 1</td>
</tr>
<tr>
<td>Load impedance</td>
<td>any resistive - inductive load within given U/I area</td>
</tr>
<tr>
<td>Load time constant (L/R)</td>
<td>typically 0.01 ... 1 sec</td>
</tr>
</tbody>
</table>

FOR SERIES CONNECTION OF 2 RECTIFIER BRIDGES

6 OR 12 WAVE RECTIFIER (WITH PROVISION FOR PARALLEL-SERIES CONNECTION OF 2 BRIDGES)
Voltage and current acquisition

Voltage indicator
2 range (199.9 and 19.99 V)
1\% digital panel meter

Current indicator
for Variant A
1 range (19.99 kA) 1\% digital panel meter

for Variants B, C
2 range (19.99, 1.999 kA)
1\% digital panel meter

Current measuring output
for Variant A
0.16 or 1.6 V ± 1 \times 10^{-3} at 16 kA

for Variants B, C
0.16 or 1.6 V ± 2 \times 10^{-4} at 16 kA

RIPPLE REQUIREMENTS (Variants B and C only) (f > 1 Hz; α ≈ 0°)

Voltage ripple
\frac{U}{U_{DC}} \leq 1 \times 10^{-3} \text{ rms; } \leq 1 \times 10^{-2} \text{ pp}

Current ripple
identical for resistive load
approx. \omega \frac{I}{R} times smaller for magnet load

CURRENT CONTROL REQUIREMENTS (Variants B and C only)

Current range
2 ranges (continuous and pulsed)

Continuous mode
0.6 \div 6 kA DC

Pulsed mode
0.8 \div 16 kA DC

Current resolution
≤ 2 \times 10^{-4} of each range

Current stability
(average DC, f \leq 1 Hz)
* long term (8 hours)
≤ 1 \times 10^{-3} of each range

** continuous, short term (min)
≤ 1 \times 10^{-4} of each range

** pulsed, pulse to pulse
≤ 1 \times 10^{-4} of each range

pulsed mode current rise
time for above stability
( regulator, filter response)
≤ 0.2 sec for resistive load

\leq 0.2 sec + 4 \times \frac{L}{R} for magnet load

* For conditions see page 12 of specification.

** Constant conditions, except for load impedance change and fast mains variations.
3. Aspects concerning the design of the supply

3.1 Versatility

In order to obtain an experimental power supply as universal as possible, extra facilities are very much appreciated, for example the feature of parallel-series connection of rectifier bridges (series connection for double voltage, at half current), or easy adjustment of current regulator and timing control.

However, it is not necessary to provide for remotely controlled operation. Therefore the power contactors may be operated manually, rectifier parallel to series operation may be made by interchanging bus-bar connections, and polarity reversal by inverting the cable connections at the load.

The power supply as a whole will not be part of a fixed installation and must therefore consist of transportable units. Cooling water will be available in all areas. In order not to heat up the environmental laboratory space, water cooling is preferable throughout. No oil or similar coolants must be used, for safety reasons. Transformers must be air cooled or water cooled. Cooling fans (if any) must not produce excessive air draught or noise.

3.2 Power part

- **Current switch.** In principle it is possible to switch the current pulses on either side of the transformer. Switching on the 3 x 380 V mains side has the advantage of lower currents (at still reasonable voltages for thyristors), but requires additional diodes on the secondary side. Switching on the 50 V rectifier side has an advantage in the case of a 12 wave rectifier, as one single secondary transformer with secondary delta-star windings is suitable while for primary switching two separate transformers are required.

- **The transformer steps** may be achieved with a tapped rectifier

PS/7328
transformer, a tapped autotransformer or a roller transformer. In the case of transformer tapping, 10 steps according to a geometrical series distribution are proposed, with ratios of $U_{n+1} : U_n \approx 1.3$, i.e. for 4, 6, 8, 10, 13, 18, 23, 30, 38 and 50 volts DC output. Thereby it is possible to adjust for intermediate voltages with rectifier angles as low as $\alpha \leq 40^\circ$ (except for the lowest ranges).

This voltage multi-range design is necessary to cope with very different loads at rather constant requirements for ripple and stability. For Variants B and C, having a filter and a regulator, the number of transformer steps may be considerably reduced, provided that the filter attenuation is sufficient.

- **Filter design.** (Variants B and C only). The filter may be designed as passive low pass, passive resonant or as a combination of passive and active elements. However, it must be noted that it must work for pulsed and continuous operation. Of course, the filter dimensions also strongly depend on the rectifier, where 6 or 12 wave rectification may be adopted. Mainly in the case of a 12 wave rectifier with a low pass filter, care must be taken to attenuate sufficiently the subharmonic frequencies, (mainly 100 Hz) introduced by line and rectifier phase asymmetries.

- **The current transducer** for measurement of the current, and with Variants B and C also used for the regulator may consist of a 0.1 m ohm direct shunt resistor or of a smaller shunt resistor followed by a precision differential amplifier. A DC current transformer may also be used.

Two 1% accuracy digital panel meters must be provided for local indication of voltage and current (c.g. type TE 340 of Tec Elec, France, price ≤ 1000.- FF), and voltage and current measuring outputs for use with external voltmeters and oscilloscopes.

PG/7326
3.3 Timing control and interlocks

- Internal timing mode. In the preferred case, all semiconductors (thyristors and diodes) are installed for 16 kA continuous current. As their thermal time constant lies in the order of the pulse length, they have almost to be designed in this way anyhow. By means of an electromagnetic - thermal overload switch on the mains contactor the output current is limited to 16 kA peak, 6 kA rms average intensity. In addition, transformers or other components may be protected with temperature monitors, i.e. with "Klixon" switches or similar interlock devices.

Then, timing may be made in a very simple way, allowing for free selection of any pulse length and any cycle time within the specified range.

However, should the semiconductors not be capable to carry 16 kA continuous current, a special timing circuit would be required, limiting the duty cycle t/T within 0.1 ... 1, according to 6000 A rms maximum average current, with an additional overload protecting device, featuring an image of the thermal time constants of the semiconductors. Instead, a monitoring timer could be used, stopping the supply automatically after a certain time, depending on the time integral of the load current, or current square. This device would have the advantage of stopping also if a stop pulse fails to arrive.

In any case it is necessary to protect the load, with a timer stopping after a certain maximum time, adjustable within 1 ... 100 sec.

- External timing mode. A start-stop trigger input must be provided for external triggering within the specified time limits.
Interlock system. The supply interlocks must provide full protection against general faults, as current overload (16 kA peak, 6 kA rms average), cooling water fault, mains fault, earth fault, and against any particular faults depending on the design of the supply (blown fuses etc.). Three additional interlock inputs must be provided for magnet faults.

The power supply must be as far as possible "fool proof". The manufacturer must clearly define any exception to that rule. In particular, all prohibited manipulations must be interlocked (switching of transformer steps under load, etc.).

3.4 Voltage and current control: ripple

Voltage adjust. For all variants (A, B, C) an unregulated voltage output node must be provided, with a resolution of $1 \times 10^{-3}$ of each of the ten voltage ranges, as given under 3.2 for the transformer steps.

This unregulated voltage node is
- the only node required for Variant A
- the unregulated node for Variant B
- the initial node of Variant C, before installation of the regulator.

Current control. (Adjustment and stability). Variant B and Variant C after installation of the regulator, must be provided for a regulated current output node. The voltage range (transformer steps) will be preselected according to load impedance and current required in order to keep the firing angle as low as $\alpha \leq 40^\circ$.

Two current ranges are defined:

- Continuous DC range: 10 \ldots 100\% of 6 kA
- Pulsed DC range: 5 \ldots 100\% of 16 kA

PS/7328
The resolution must be higher than $2 \cdot 10^{-4}$ of each current range.

The current stability and ripple given under 2 (Table) are defined for resistive loads, firing angle $\alpha \approx 0^\circ$ and for the following load, line voltage and cooling conditions:

- $\pm 10\%$ change of load impedance
- $\pm 5\%$ slow mains amplitude variations
- $\pm 2\%$ fast mains amplitude variations
- $\pm 1\%$ mains asymmetry
- $\pm 1\%$ mains frequency change and phase instability (slow and fast)
- $\pm 2^\circ C$ change of cooling water temperature
- $\pm 5^\circ C$ change of ambient air temperature.

For the short term stability (1 minute, or pulse-to-pulse) only the terms for load impedance change and fast mains variations need to be considered.

It is assumed that the specified performances can be achieved with appropriate industrial grade equipment, without exaggerated costs for critical trimming or exceptional components. However, should this not be the case, it is understood that the matter may be revised with tenderers.
Basic Diagrams

6 wave rectifier

380 V 50 Hz

I

II

12 wave rectifier

380 V 50 Hz

III

IV

Pulsed current area

Legend:

Tr1, Tr2: Auto - plus rectifier transformer / or tapped rectifier transformer
Th: Thyristors, several in parallel
Di: Diodes, several in parallel
} Series - parallel connections of rectifier bridges
) idem, with interphase transformer for parallel connections
F: Filter
U, I: Voltage, current measuring outputs
QUESTIONNAIRE

(Minimum of technical information required for tenders). Please underline and fill in:

POWER PART

- Basic diagram (I...IV)
- Transformers
  - Tr. cooling
  - Number of tr. steps
- Thyristors
  - Series-parallel connection facilities of rectifier
  - Rectification
  - Thyristors (number x type used)
  - Diodes (number x type used)
  - Max. currents for thyristors + diodes
- Timing control
- Filter design
  - F. attenuation
  - F. rise time

VARIANFT

(type ....... , or/as attached hereto
auto-transformer; tapped rectifier tr.
air, forced air, water
primary -, secondary side switching
yes, no
6 wave, 12 wave
...... x ....
...... x ....
...... kA peak; ...... kA rms
free selection of t and T;
automatic limiter t/T = f(I);
other method
passive low pass; passive resonant
active ; mixed
...... cps : ......; ...... cps : ......;
...... ns : 63%; ...... ns : 98% ;

VOLTAGE, CURRENT ACQUISITION

Voltage indicator
Current indicator
Current transducer
  - Output signal
  - Cooling

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CURRENT CONTROL
Regulator loops
Reference source (type)
Amplifiers (type)
Gate control set (type)
Adjustments for various loads

OVERLOAD PROTECTION, INTERLOCKS
Standard interlocks
Special protections
Faults against which supply is not fully protected

MISCELLANEOUS FEATURES, COMMENTS