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Abstract

This document describes the detailed specifications of the power converters for the solenoids of the new Electron Cyclotron Resonance Ion Source GHIISI at GSI

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1. Purpose and Classification of the Document

This document describes the detailed specifications of the power converters for the solenoids of the new 18 GHz ECR ion source GHIISI at GSI. General technical requirements of all parts and components for power converters are given in the Common Specification for power converters [2]. General legal and technical requirements which are valid for all technical systems of GSI/ FAIR are described in the General Specification [1] and technical guidelines which are referred in this document.

However, statements given in this document override the statements given in the general specification, the common specification for power converters and the technical guidelines.

Contracting body for the equipment described in this document is “GSI Helmholtzzentrum für Schwerionenforschung GmbH (GSI)”. So, all further references to the term ‘the Company’ will refer to GSI.

2. Abbreviations, Terms and Definitions

ACU	Adaptive Control Unit
DCCT	DC Current Transducer
EMC	Electromagnetic Compatibility
ECR	Electron Cyclotron Resonance
ECRIS	Electron Cyclotron Resonance Ion Source
FAIR	Facility for Antiproton and Ion Research
FAT	Factory Acceptance Test
GSI	GSI Helmholtzzentrum für Schwerionenforschung GmbH
GHIISI	GSI Heavy-Ion Ion Source Injector
UNILAC	Universal Linear Accelerator
LV	Low Voltage
PC	Power Converter
SAT	Site Acceptance Test
SIS18	Schwerionensynchrotron
FT	Freewheeling Thyristors. Antiparallel thyristors to freewheel the output of the PC.

Table 2-1: List of Abbrevations

3. Scope of the technical system

3.1. System Overview

A new ECR ion source, GHIISI, is under development in GSI, whose plasma will be heated by microwaves via electron cyclotron resonance process. The heating of plasma will be realized by using 18 GHz or/and 14 GHz microwave frequency depending on the ion beam requirements. The adequate plasma heating and confinement requires a certain magnetic field configuration being a superposition of hexapole and solenoid magnetic fields.

The magnetic field will be produced using three solenoids and a permanent magnet hexapole. Three power converters capable of feeding the solenoids with the necessary current are required.

3.2. Structure of the Power Converters

In general, each power converter shall consist of two parts:

1. Power part,

   It is supplied by a 400V, 3-phase Common supply system, C1 (Sec. 5.1 of [2])

2. Control part,

   It is supplied by a 400V, 3-phase Common supply system, C1 (Sec. 5.1 of [2]).

Table 4-1 gives the technical parameters for the power part. The design principles for the main components and functionalities of the power part can be found in Sec. 4 of [2] and 8.5 of [2].

From the standardization point of view, it is mandatory for the power converter to be compatible with the ACU systems and the DCCTs, which will be provided by the Company.

The ACU system has to be integrated in the control part of the power converter.

One high precision DCCT (per power converter) is needed and it must be installed at the output of the power converter.

Further details can be found in Sec. 8.3 of [2], 8.4 of [2], [4] and [6].

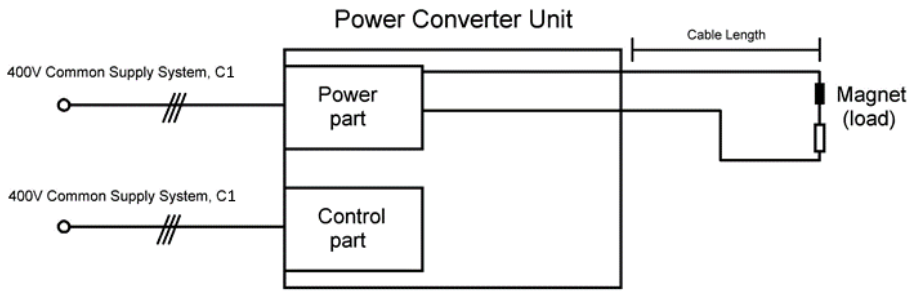

Figure 1: Power Converter Set-up

Each power converter shall supply the load through single conductor 150 mm^2 power cables. The cable length is determined by the physical distance between the power converter and the magnet (Figure 1) and the routing of the cable trays.

3.3. Content of Delivery

The contractor has to deliver the following power converters:

Item №	PC Description	PC Type	№ of PCs
1	Solenoid Injection-Extraction	SVE 8A-U	2
2	Solenoid Middle	SVE 8B-U	1

Table 3-1: The type of the power converters to be delivered by the contractor.

Provisions of the contractor:

- Design of the power converters listed in Table 3-1, including CDR and FDR (see Sec. 5);
- Manufacturing of the power converters mentioned in Table 3-1;
- Integration of the ACU systems, DCCTs, and further provided electronics;
- Factory Acceptance Test (FAT) for all power converter listed in Table 3-1 (see Sec. 5.3.1);
- Packaging and transportation of the PCs to the final location (in GSI);
- Installation and assembly (if needed) at final location (in GSI);
- Site Acceptance Test (SAT) for all power converters listed in Table 3-1 (see Sec. 5.3.2) at final location (in GSI);
- Spare parts as mentioned in Sec. 3.4;
- Documentation (see Sec. 6).

Provisions of the Company:

- The load cables connecting the power converter output to the load will be provided as well as mounted by the Company;
- Input power cables connecting the power converter input to the low voltage distributions (including ground) will be provided as well as mounted by the Company;
- External interlock cables will be provided as well as mounted by the Company;
- Connection to the water system;

- 1 ACU system[1] (Sec. 8.3 of [2]);
- 1 DCCT measuring head and respective electronics including the cable[1] (Sec. 8.4 of [2]);

3.4. **Spare Parts**

The following spare parts, if present in the design, must be provided by the Contractor:

Component	**Quantity in relation to the total component number of the same type[2]**
Power semiconductors (rectifier diodes)	50%
Power semiconductors (IGBTs)	50%
Power capacitors[3] (DC-link, output filter, etc.)	30%
Power resistors (charging, discharging, etc.)	30%
Contactors (main contactor, auxiliary contactors)	30%
Water flow control meter	2 pieces
Line voltage monitoring	2 pieces
Isolation monitoring	2 pieces
IGBT driver cards	50%
Voltage sensor cards	2 pieces
Current sensor cards	2 pieces
Control cards	2 pieces
Power fuses	50%

Table 3-2: List of spare parts

It is to be noted that if the components are assembled in stacks (e.g IGBT/Thyristor stacks) or pre-designed modules, at least one complete stack/module of each type with the corresponding mechanical, electrical and/or cooling components per system have to be provided. Also, the tools for servicing the stacks must be provided.

[1] Components will be delivered to the contractor, by the Company, as per the schedule.

[2] At minimum one piece of each component type has to be delivered

[3] In case of electrolytic capacitors, only one piece per type must be provided as spare

3.5. Lifetime of the components

The power converters must be designed to operate for 7250 hours (excluding natural degradation processes) per year for at least 25 years. See also Type C in Sec. 8.1.3 of [2].

3.6. Interfaces

The power converter will have the following interfaces:

1. Electrical inputs for the electrical supply systems (see Sec. 3.2 and 4.3)
2. Integration of the ACU system (see Sec. 8.3 and 8.4 of [2])
3. Inputs for interlocks (see Sec. 4.5)
4. Connection to the water system (see Sec. 4.7)
5. Electrical outputs (see Sec. 4.2)
6. Mechanical dimensions (interface to building, see Sec. 4.7)
7. Ground connection (see 4.4).

4. Technical Specification

4.1. Technical Parameters

Power Converter type	SVE 8A-U	SVE 8B-U
Maximum current, I_{max}, A	1210	660
Nominal current, I_N, A	1100	600
Range of load current, I_{min}…I_N, A	110…1100	60…600
Maximum rise time from 0 to I_N, s	10	10
Maximum fall time from I_N to 0, s	10	10
No. of magnets in series	1	1
Low field inductance of the magnet, L_{Lm}, mH	97	21
High field inductance of the magnet, L_{Hm}, mH	75	21
Total resistance of the load, R_L, mΩ	102.6	61.9
N° of cables in parallel	4	2
Cross section of each cable, mm²	150	150

Permissible total deviation absolute: $\delta_2 I$ ($=\Delta I/I_N$)	$\pm 1 \times 10^{-4}$	$\pm 1 \times 10^{-4}$
Maximum cycle frequency, f, mHz	100	100
Cabinet dim. W x D, m ; H = 1.7 m incl. socket and roof	1.6 x 0.8	1.0 x 0.8

Table 4-1: Technical parameters

Beside the technical parameters of Table 4-1 the following aspects have to be considered:

1. The power converters must operate in pulsed mode and in DC mode (type A and C in Subsec. 8.1.3 of [2]). It is to be noted that the cycle frequency mentioned in Table 4-1 is calculated by assuming an extreme case with no flat top.
2. In DC mode, constant load currents up to I_N will be applied.
3. The permissible voltage ripple of the output voltage must be as per the given in Section 8.2 of [2].
4. The power converters must be equipped with Free-wheeling Thyristors (FTs). In case of an interlock, the FTs must be activated simultaneously with the PC turn off. The current through the FTs must be monitored (for example using AC current transducers) in order to identify the respective malfunctioning.

4.2. Electrical Outputs

Four (two) 150mm^2 single conductor power cables in parallel will be used to connect the power converter output to the respective load. Power converter outputs have to be designed according to the used cable type.

A possibility to reverse the polarity of the power converter outputs without unscrewing cable terminals has to be foreseen.

4.3. Electrical Inputs

As mentioned in Sec. 3.2, the power converter has to be equipped with two electrical inputs. The dimensions of the input terminals for the power part and the rating of the fuse placed in the low voltage distribution (gG characteristic, see IEC 60269) shall be proposed by the contractor and approved by the Company.

The Input terminals for the control part must be equipped with terminals of 2.5 mm² and the fuse rating in the low voltage distribution will be 16 A (B characteristic, see EN 60898).

4.4. Grounding of the Power Converters

The power converters are usually grounded by the input cable. In addition to that they have to be connected to the equipotential bonding rail (copper bus bar) inside the false floor. Therefore a

possibility to connect a copper strap to the mounting plate of the power part (the plate where the switch mode circuit is located) has to be foreseen and done by the contractor (the size of the connector of the copper strap is M10).

4.5. **Interlocks**

All the interlocks to be applied are mentioned in subsec. 8.5.10 in Common specification [2].

In addition to that, beam interlock system (version ‘A’ in subsec. 8.5.11 in [2]) has to be foreseen. In contrast to [2] a 2-pole connector has to be used.

The following Interlock sockets for each power converter have to be foreseen:

- SV5 for beam interlock system ‘A’.
- SV6 for the interlocks of the supplying magnet

The SV5 socket for beam interlock is a 2 pin connector of type 0S.302.CLL 0S.302.CYL for crimping. The SV6 socket for the interlocks are 12-pin female sockets AEGA-114-FR-11-00-0103-200 for crimping.

The pin assignment for SV5 is presented in Sec. 8.5.11 of [2]. Pin 3 is the equivalent to pin 2. The pin assignment for SV6 is presented in Figure 25 of [4].

4.6. Electrical Supply System

All the power parts of the power converters are mentioned in this document are going to be fed by the 20 kV/400 V transformer on the common supply system C1 (Sec. 4.1 in [2]).

All the electrical interfaces for electronic parts are going to be fed by a 20kV/400V transformer in the common supply system C1 (Sec. 4.1 in [2]).

4.7. System Environment and Constraints

All the environmental conditions and constraints that shall be considered, like water cooling system and mechanical properties of the installation location as well as the interactions of the power converters with the installation location environment, are described in Sec. 6.1 of [2], Sec. 6.2 of [2] and Sec. 7 of [2].

In contrast to Sec. 6 of [2], the power converters will be installed on the normal floor. All cables and water hoses must be inserted from the bottom.

The dimensions of the maximum available installation place are given in Table 4-1.

4.8. Labelling of Power Converters

The labelling of the power converter has to be done according to Subsec. 8.5.8 of [2]. The reference to the document [8] in Subsec. 8.5.8 of [2] is replaced by [5] of this document. The CID numbers for the specified power converters are :

CID:03000708617 SVE 8A-U
CID:03000708624 SVE 8A-U
CID:03000708631 SVE 8B-U

Additionally, a plate indicating the type and the number of the power converter has to be centrally placed on the front door where the user interface (ACU) is positioned.

4.9. Transportation of Power Converter

The transportation and installation of the produced power converters shall be performed taking into account Sec. 10 of [2].

Additionally, transportation within the Company will be assisted by the Company.

The packaging of the power converters has to be labelled with the cabinet name (to ensure their appropriate distribution to the respective places for testing).

5. Quality Assurance, Tests, and Acceptance

General design aspects, quality assurance and, tests and acceptance are specified in the General Specification [1] and in the Contract. Main and specific points for the systems specified in this document are listed below and they substitute what is mentioned in Sec. 9 of [2] and Sec. 9.1 of [2].

The realization process of the specified systems consists of the following phases:

- Design development and preparation of the production:
  - Design development;
  - Conceptual Design Review (CDR);
  - Creation of manufacturing documents;
  - Final Design Review (FDR).
- Production of the systems, FAT and shipping;
- Installation, commissioning and testing at the Company site (SAT).

Periodic status reports are mandatory during all the phases. The contractor and the Company have to agree/discuss about the reporting intervals. The deliverables of each phase and the corresponding rights will become the property of the Company.

Additionally, must be taking into account:

- The set of documents, listed in Sec. 11.1 of [2], have to be delivered during the tendering process;
- Oppositely to what is mentioned in [1], no pre-series prototype and the corresponding acceptance procedures will be done;
- The shipment of the power converter must be regulated and released by the Company.

5.1. Design Reviews

Conceptual Design Review (CDR) and Final Design Review (FDR) between the company and the manufacturer shall be done to complete the “Design development and preparation of the production” phase, mentioned in Sec. 5.

During CDR, design documents will be discussed. More in detail, the following information have to be provided:

1. Functional description of all the components;
2. Explanation of design criteria according to Sec. 8.5 of [2];
3. Technical data;
4. Block diagrams;
5. Manufacturer/type of all main components;
6. Description of interface (control interfaces and interfaces to the environment);
7. Simulation of the operation modes given in the corresponding detailed specification;
8. Draft version of the production plan;

9. Test concept to ensure testability during FAT and SAT;
10. Definition of the critical components which are operated on the verge of or beyond to their specification limits;
11. Draft version of the Risk / Hazard Assessment.

During FDR, additionally to the design documents, manufacturing documents will be discussed. More in detail, the following information have to be provided:

1. A description of the complete power converter;
2. Detailed specification of all main components (technical and mechanical data) (i.e. Cabinet, transformer, inductor, capacitor bank, arrangement of semiconductors, placement of DCCT-head);
3. Drawings or preferably 3D-models of the physical configuration of the complete power converter (components placement inside the cabinet);
4. Block diagrams and schematics of the control loops;
5. Complete schematics of all the electrical circuits;
6. Complete specification of all the interfaces (electrical, mechanical, building, media, software, etc.);
7. List of recommended spare parts;
8. Provision of design and production documents (production plan, quality plans, work instructions and test instructions);
9. Test plans and templates of test protocols for FAT and SAT;
10. Adjustment plan if necessary;
11. Draft version of the transportation specification (dimensions and weights with and without packaging).
12. Declaration of conformity;
13. Risk / Hazard assessment;
14. Draft version of the user manual.

Draft versions of documents must be available at least 14 days before each design review respectively.

A formal acceptance given in written form by the Company after each review is mandatory. This means that the production of the documents for FDR shall start only after the CDR is complete and the respective design documents are accepted by the Company.

In general, design and manufacturing documents together contain all needed information to start the production without any further R&D activities.

5.2. **Production of the systems**

The production phase starts after successful completion of the FDR.

During this phase, the contractor shall fabricate the systems by implementing the production plans approved during the FDR (see Sec. 5.1).

No pre-series prototype shall be produced and approved.

5.3. Tests and Acceptance

Concerning the details about the tests and acceptance refer to Sec. 9.2 and 9.3 of [2]. Additionally, consider the following points:

5.3.1. Factory Acceptance Test (FAT)

The FAT has to be performed according to the procedure described in Sec. 9.2.2 of [2]. The tests can be performed using a test load.

5.3.2. Site Acceptance Test (SAT)

SAT consists of 3 parts (SAT Aa, SAT Ab and SAT Ba, see Sec. 9.3 of [2]). They will be performed by the Contractor at the final location of the power converters. Please note, passivation of the cooling system as described in Sec. 9.3.1 of [2] doesn't need to be done during the SAT Ab. SAT Ab only involves the scouring of the cooling system with de-ionised water.

6. Documentation

Concerning the details about the documentation refer Sec. 11 of [2]. According to 2006/42/EG, the assembly, operation or service manual has to be supplied by the contractor at least in German or preferably in English and German (in contrast to Sec. 11 of [2]).

7. Related Documents

[1] General Specification, F-GS-PMO-en-General_Specification-V004

[2] Common Specification on Power Converters F-CS-PC-01e

[3] Electrical Design Rules and Regulations F-TG-ET-01e

[4] Integration of Adaptive Control Unit (ACU) for Switch Mode Power Converters

[5] Component ID Barcode System F-TG-B-05e

[6] DCCT class 3 Installation in Power Converters, F-TN-PC-0005e