

|                                                                                                                                                                     |                                    |                     |                    |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------|---------------------|--------------------|
| Configuration Management and Documentation                                                                                                                          | Document Type                      | Document Number:    | Date<br>18.02.2020 |
|   | <b>Detailed Specification (DS)</b> | F-DS-EPS-en-PC_0022 | Page<br>1 of 17    |

|                         |                                                                                                                 |
|-------------------------|-----------------------------------------------------------------------------------------------------------------|
| Document Title:         | <b>Power Converter for SIS100 Fast Pulsed Quadrupole Magnet</b>                                                 |
| Description:            | This document describes detailed specifications of power converter for the SIS100 Fast Pulsed Quadrupole Magnet |
| Division/ Organization: | GSI-EPS                                                                                                         |
| Field of Application:   | FAIR GmbH and GSI GmbH                                                                                          |

#### Document History:

| Version | Prepared by:            | Checked, Date                                    | Released, Date                                       | Comment                                   |
|---------|-------------------------|--------------------------------------------------|------------------------------------------------------|-------------------------------------------|
| V 0.1   | V. Plyusnin, 14.02.2018 |                                                  |                                                      | Draft version                             |
| V 1.0   | V. Plyusnin, 12.03.2018 | D. Ondreka, 20.09.2018<br>P. Spiller, 09.12.2019 | H. Schwarz, 20.03.2018<br>B. Schönfelder, 23.03.2018 | <b>First version</b>                      |
| V 2.0   | V. Plyusnin, 18.02.2020 |                                                  |                                                      | <b>Second version</b><br>Sec. 4.1 updated |



|                                                                                                                                                                     |                                        |                     |                    |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------|---------------------|--------------------|
| Configuration<br>Management and<br>Documentation                                                                                                                    | Document Type                          | Document Number:    | Date<br>18.02.2020 |
|   | <b>Detailed Specification<br/>(DS)</b> | F-DS-EPS-en-PC_0022 | Page<br>2 of 17    |

### Abstract

This document describes detailed specifications of power converter for the Fast Pulsed Quadrupole Magnet of SIS100 (Heavy-Ion Synchrotron 100).

PSP: 2.8.3.3.6.1

|                                                                                   |                                    |                     |                    |
|-----------------------------------------------------------------------------------|------------------------------------|---------------------|--------------------|
| Configuration Management and Documentation                                        | Document Type                      | Document Number:    | Date<br>18.02.2020 |
|  | <b>Detailed Specification (DS)</b> | F-DS-EPS-en-PC_0022 | Page<br>3 of 17    |

### ***Table of Contents***

|                                                                        |    |
|------------------------------------------------------------------------|----|
| 1. Purpose and classification of the document.....                     | 5  |
| 2. Abbreviations, terms and Definitions.....                           | 5  |
| 3. Scope of the technical System.....                                  | 6  |
| 3.1. System Overview .....                                             | 6  |
| 3.2. Structure of Power Converters .....                               | 7  |
| 3.3. Content of Delivery .....                                         | 8  |
| 3.4. Spare Parts.....                                                  | 9  |
| 3.5. Interfaces.....                                                   | 9  |
| 4. Technical Specification .....                                       | 10 |
| 4.1. Technical Parameter .....                                         | 10 |
| 4.2. Electrical Outputs.....                                           | 12 |
| 4.3. Electrical Inputs (Power Part, Control Part) .....                | 12 |
| 4.4. Grounding of the Power Converters .....                           | 12 |
| 4.5. Interlocks .....                                                  | 12 |
| 4.6. Interaction of the PC with the MPS .....                          | 12 |
| 4.7. Labelling of Power Converters .....                               | 14 |
| 4.8. Electrical Supply System.....                                     | 14 |
| 4.9. System Environment and Constraints .....                          | 14 |
| 4.10. Transportation of Power Converter .....                          | 14 |
| 5. Quality Assurance, Procedures for Construction and Production ..... | 14 |
| 5.1. Design Reviews .....                                              | 15 |
| 5.2. Production of the systems.....                                    | 16 |
| 5.3. Tests and Acceptance .....                                        | 16 |
| 5.3.1. Factory Acceptance Test (FAT) .....                             | 16 |
| 5.3.2. Site Acceptance Test (SAT) .....                                | 17 |
| 6. Documentation .....                                                 | 17 |
| 7. Related Documents .....                                             | 17 |
| 8. Attached Documents .....                                            | 17 |

|                                                                                   |                                        |                     |                    |
|-----------------------------------------------------------------------------------|----------------------------------------|---------------------|--------------------|
| Configuration<br>Management and<br>Documentation                                  | Document Type                          | Document Number:    | Date<br>18.02.2020 |
|  | <b>Detailed Specification<br/>(DS)</b> | F-DS-EPS-en-PC_0022 | Page<br>4 of 17    |

#### List of Tables:

|                                                                                              |    |
|----------------------------------------------------------------------------------------------|----|
| Table 2-1: List of Abbreviations .....                                                       | 5  |
| Table 3-1: Type and PSP codes of the power converters to be delivered by the contractor..... | 8  |
| Table 3-2: List of spare parts.....                                                          | 9  |
| Table 4-1: Technical Parameters.....                                                         | 10 |
| Table 4-2: Actions to be taken in case of interlock.....                                     | 13 |

#### List of Figures:

|                                                                                           |    |
|-------------------------------------------------------------------------------------------|----|
| Figure 1: 3D-model of a Fast Pulsed Quadrupole Magnet for SIS100 .....                    | 6  |
| Figure 2: Power Converter Set-up .....                                                    | 7  |
| Figure 3: Example of a current profile needed for the SIS100 Fast Quadrupole Magnet ..... | 11 |
| Figure 4: Action diagram during an interlock.....                                         | 13 |

|                                                                                   |                                    |                     |                    |
|-----------------------------------------------------------------------------------|------------------------------------|---------------------|--------------------|
| Configuration Management and Documentation                                        | Document Type                      | Document Number:    | Date<br>18.02.2020 |
|  | <b>Detailed Specification (DS)</b> | F-DS-EPS-en-PC_0022 | Page<br>5 of 17    |

## 1. Purpose and classification of the document

This document describes technical requirements of the power converter dedicated to feed the Fast Pulsed Quadrupole Magnet of SIS100 (Heavy-Ion Synchrotron) inside FAIR project.

General technical requirements for all the parts and components of the power converters are given in the Common Specifications for power converters [2]. General, legal and technical issues are given in the General Specifications [1] and technical guidelines "Electrical Design Rules and Regulations" [3], respectively.

*However, statements made in this document override the ones in all other documents: the general specifications, the common specifications for power converters and the technical guidelines.*

Contracting body for the equipment described in this document is FAIR GmbH. Therefore, all further references to the term 'the Company' will refer to FAIR GmbH.

## 2. Abbreviations, terms and Definitions

|            |                                                                                                     |
|------------|-----------------------------------------------------------------------------------------------------|
| ACU        | Adaptive Control Unit                                                                               |
| CID        | Component-ID (identification number)                                                                |
| CDR        | Conceptual Design Review                                                                            |
| DC         | Direct Current                                                                                      |
| DCCT       | DC Current Transformer                                                                              |
| $\delta I$ | Permissible deviation of the power converter output current                                         |
| FAIR       | Facility for Antiproton and Ion Research                                                            |
| FAIR GmbH  | International GmbH under German law aiming to realize the FAIR project – acting as contracting body |
| FAT        | Factory Acceptance Test                                                                             |
| FDR        | Final Design Review                                                                                 |
| Frame      | 19" rack IEC 297-3                                                                                  |
| FT         | Freewheeling Thyristors. Antiparallel thyristors to freewheel the output of the PC.                 |
| gG         | operating class / utilization category for melting fuses (see IEC 60269)                            |
| GSI        | GSI Helmholtz-Zentrum für Schwerionenforschung                                                      |
| MFU        | Multifunction module                                                                                |
| MPS        | Machine Protection System                                                                           |
| PC         | Power Converter                                                                                     |
| PSP        | Project Structure Plan                                                                              |
| RIB        | Rare Isotope Beam                                                                                   |
| SAT        | Site Acceptance Test                                                                                |
| SIS100     | Heavy-Ion Synchrotron 100 ( <i>Schwerionen Synchrotron 100</i> )                                    |
| SM_x       | Switch Mode_x                                                                                       |

**Table 2-1: List of Abbreviations**

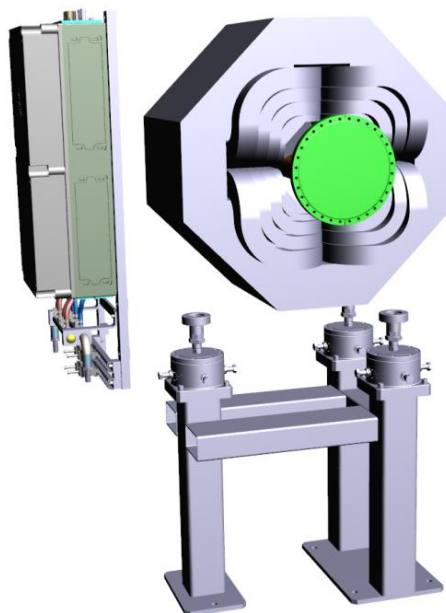
|                                                                                   |                                    |                     |              |
|-----------------------------------------------------------------------------------|------------------------------------|---------------------|--------------|
| Configuration Management and Documentation                                        | Document Type                      | Document Number:    | Date         |
|  | <b>Detailed Specification (DS)</b> | F-DS-EPS-en-PC_0022 | 18.02.2020   |
|                                                                                   |                                    |                     | Page 6 of 17 |

### 3. Scope of the technical System

#### 3.1. System Overview

The Heavy Ion Synchrotron SIS100 is an essential part of the new Antiproton and Ion Research Facility (FAIR) in Darmstadt. It will use the present accelerators of GSI (universal linear accelerator UNILAC and synchrotron SIS18) as an injector. The circumference of SIS100 is about 1090 meters; five times the circumference of the present SIS18.

SIS100 is divided in 6 sectors. Each sector has 1 arc and 1 straight section. The Fast Pulsed Quadrupole magnet is part of the slow extraction system of the SIS100. It will drive the tune of the beam particles into resonance to trigger the slow extraction process. For this, the magnet must be ramped up to the maximum field in a rather short time of 100 ms.



**Figure 1: 3D-model of a Fast Pulsed Quadrupole Magnet for SIS100**

To feed the Fast Pulsed Quadrupole magnet, one ramped power supply, capable of reaching a nominal current ( $I_N$ ) of 1485 A within a time of 0.1s with an absolute accuracy of  $1 \times 10^{-4} \cdot I_N$  is needed. The maximum output voltage of this power converter shall be of about 210V.

The power converter shall have two independent parts. The power part, which is under the responsibility of the manufacturer and the control part, which is mainly designed and provided by the Company. More in detail, 1 ACU system and 1 DCCT per power converter are provided by the Company.

The connection between the power converter and the corresponding magnet will be done using four coaxial cables in parallel with a cross-section of 185 mm<sup>2</sup> each, provided and connected by the Company.

|                                            |                                    |                     |              |
|--------------------------------------------|------------------------------------|---------------------|--------------|
| Configuration Management and Documentation | Document Type                      | Document Number:    | Date         |
| <b>FAIR GSI</b>                            | <b>Detailed Specification (DS)</b> | F-DS-EPS-en-PC_0022 | 18.02.2020   |
|                                            |                                    |                     | Page 7 of 17 |

### 3.2. Structure of Power Converters

The power converter can be divided in two parts:

1. Power part

It is supplied by a 400V, 3-phase Pulsed Power supply system PP1/PP2 (Sec. 2.3 of [3]).

2. Control part

It is supplied by a 400V, 3-phase Common supply system C2 or C3 (Sec. 2.3 of [3]).

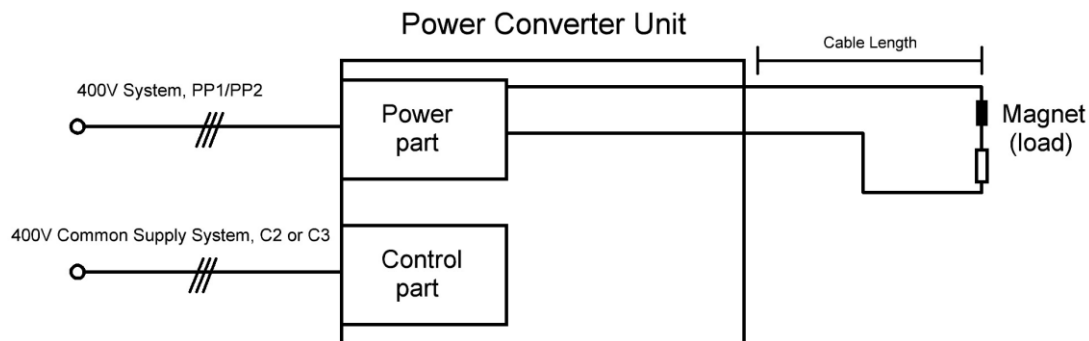
Table 4-1 gives the technical parameters for the power part. The design principles for the main components and functionalities of the power part can be found in Sec. 4 of [2] and 8.5 of [2].

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 [7].



**Figure 2: Power Converter Set-up**

Each power converter shall supply the load through four coaxial power cables, connected in parallel (see Sec. 4.2).

The cable length is determined by the physical distance between the power converter and the magnet (Figure 2) and the routing of the cable trays. The maximum cable length in this case is of about 65 meters. The connection of the PCs shall be done according to Sec. 8.5.13 of [2].

|                                                                                   |                                    |                     |                    |
|-----------------------------------------------------------------------------------|------------------------------------|---------------------|--------------------|
| Configuration Management and Documentation                                        | Document Type                      | Document Number:    | Date<br>18.02.2020 |
|  | <b>Detailed Specification (DS)</b> | F-DS-EPS-en-PC_0022 | Page<br>8 of 17    |

### 3.3. Content of Delivery

The contractor has to deliver the following power converters:

| Item № | PC Description  | PC Type | PSP Code    | № of PCs |
|--------|-----------------|---------|-------------|----------|
| 1      | Fast Quadrupole | 1S.C6   | 2.8.3.3.6.1 | 1        |

**Table 3-1: Type and PSP codes 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. 5.1);
- Manufacturing of power converters listed in Table 3-1;
- Integration of the ACU systems, DCCTs and further provided electronics;
- Factory Acceptance Tests, FAT, for all assembled power converters (see Sec. 5.3.1);
- Packaging, transportation to and unloading at the Company's location;
- Cable connectors and, the clamp and rack assembly (see Sec. 4.8 and [6]) for all load cables;
- Final assembly (if needed) of the power converters at final location for testing;
- Site Acceptance Tests (SAT), for all assembled power converters (see Sec. 5.3.2);
- Documentation (see Sec. 6);
- Spare parts as described in Sec. 3.4.

#### Provisions of the Company:

- Internal transportation of the power converters to the final location for testing;
- 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;
- Interlock cables will be provided as well as mounted by the Company;
- Connection to the water system;
- 1 ACU system<sup>1</sup> (Sec. 8.3 of [2]);
- 1 DCCT<sup>1</sup> (Sec. 8.4 of [2]);
- 1 Interface Card to connect the PC and the MPS<sup>2</sup>.

<sup>1</sup> Components will be delivered to the contractor, by the Company, as per the schedule.

|                                                                                   |                                    |                     |                    |
|-----------------------------------------------------------------------------------|------------------------------------|---------------------|--------------------|
| Configuration Management and Documentation                                        | Document Type                      | Document Number:    | Date<br>18.02.2020 |
|  | <b>Detailed Specification (DS)</b> | F-DS-EPS-en-PC_0022 | Page<br>9 of 17    |

### 3.4. Spare Parts

The following spare parts are necessary:

| Device Name                                       | Quantity in relation to the total device number of the same type <sup>2</sup> |
|---------------------------------------------------|-------------------------------------------------------------------------------|
| Power semiconductors (rectifier diodes)           | 50% or min 6 pieces                                                           |
| Power semiconductors (IGBT, Thyristors)           | 50% or min 2 pieces                                                           |
| Power capacitors (DC-link, output filter)         | 1%                                                                            |
| Contactors (main contactor, auxiliary contactors) | 1%                                                                            |
| Water flow control meter                          | 1%                                                                            |
| Line voltage monitoring                           | 1%                                                                            |
| IGBT driver cards                                 | 50% or min 2 pieces                                                           |
| Thyristor driver cards                            | 1%                                                                            |
| Voltage sensor cards                              | 1%                                                                            |
| Current sensor cards                              | 1%                                                                            |
| Power fuses                                       | 15%                                                                           |

**Table 3-2: List of spare parts**

### 3.5. Interfaces

The power converter will have the following interfaces:

1. Electrical inputs for the electrical supply systems (see Sec. 3.2 and 4.8)
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. 4.9);
5. Electrical outputs (see Sec. 4.2);
6. Mechanical dimensions (interface to building, see Sec. 4.10);
7. Interface to MPS system (see Sec. 4.6).
8. Ground connection (see Sec. 4.4).

<sup>2</sup> At least one piece of each device has to be delivered, if not stated otherwise.

|                                                                                   |                                    |                     |               |
|-----------------------------------------------------------------------------------|------------------------------------|---------------------|---------------|
| Configuration Management and Documentation                                        | Document Type                      | Document Number:    | Date          |
|  | <b>Detailed Specification (DS)</b> | F-DS-EPS-en-PC_0022 | 18.02.2020    |
|                                                                                   |                                    |                     | Page 10 of 17 |

## 4. Technical Specification

### 4.1. Technical Parameter

| PC type                                                               | 1S.C4                  |
|-----------------------------------------------------------------------|------------------------|
| PC description                                                        | Fast Quad. PC          |
| Maximum current <sup>3</sup> , $I_{max}$ , A                          | 1640                   |
| Nominal current, $I_N$ , A                                            | 1485                   |
| Range of load current, A                                              | 0 ... 1485             |
| Current ramping rate $di/dt$ , A/s                                    | $\pm 14850$            |
| Maximum bending time, ms                                              | 20                     |
| Cycle frequency, $f$ , Hz                                             | 5                      |
| Permissible total deviation absolute: $\delta_2 I (= \Delta I / I_N)$ | $\pm 1 \times 10^{-4}$ |
| Nº of magnets in series                                               | 1                      |
| Resistance of the magnet, $R_m$ , m $\Omega$                          | 13                     |
| Low field inductance of the magnet, $L_m$ , mH                        | 16.8                   |
| High field inductance of the magnet, $L_m$ , mH                       | 13.4                   |
| Nº of cables in parallel                                              | 4                      |
| Cross section of each conductor, mm <sup>2</sup>                      | 185                    |
| Resistance of load cables, $R_L$ , m $\Omega$                         | 2.75 ... 3.9           |
| Maximum length of load cables, m                                      | 65                     |
| Max. cabinet dim.<br>W x B, m ; H = 2.2 m                             | 2.4 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 Ramping 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.

<sup>3</sup> There is no specific requirement for the rise time and accuracy from  $I_N$  to  $I_{max}$

|                                                  |                                        |                     |                    |
|--------------------------------------------------|----------------------------------------|---------------------|--------------------|
| Configuration<br>Management and<br>Documentation | Document Type                          | Document Number:    | Date<br>18.02.2020 |
| <b>FAIR</b> <b>GSII</b>                          | <b>Detailed Specification<br/>(DS)</b> | F-DS-EPS-en-PC_0022 | Page<br>11 of 17   |

3. The permissible voltage ripple of the output voltage must be as per the given in Section 8.2 of [2]. Additionally, the normalized voltage ripple during flattop ( $U_{\text{NFTripple}}$ ) at any current level from 0 to 1485 A ( $I_{\text{FT}}$ ) must fulfil the following requirement (limits in Section 8.2 of [2] still valid):

$$U_{\text{NFTripple}}(f) \leq \pm I_{\text{FT}} \times 1 \times 10^{-5} \times 2\pi \times f_{\text{min}} \times L(I)$$

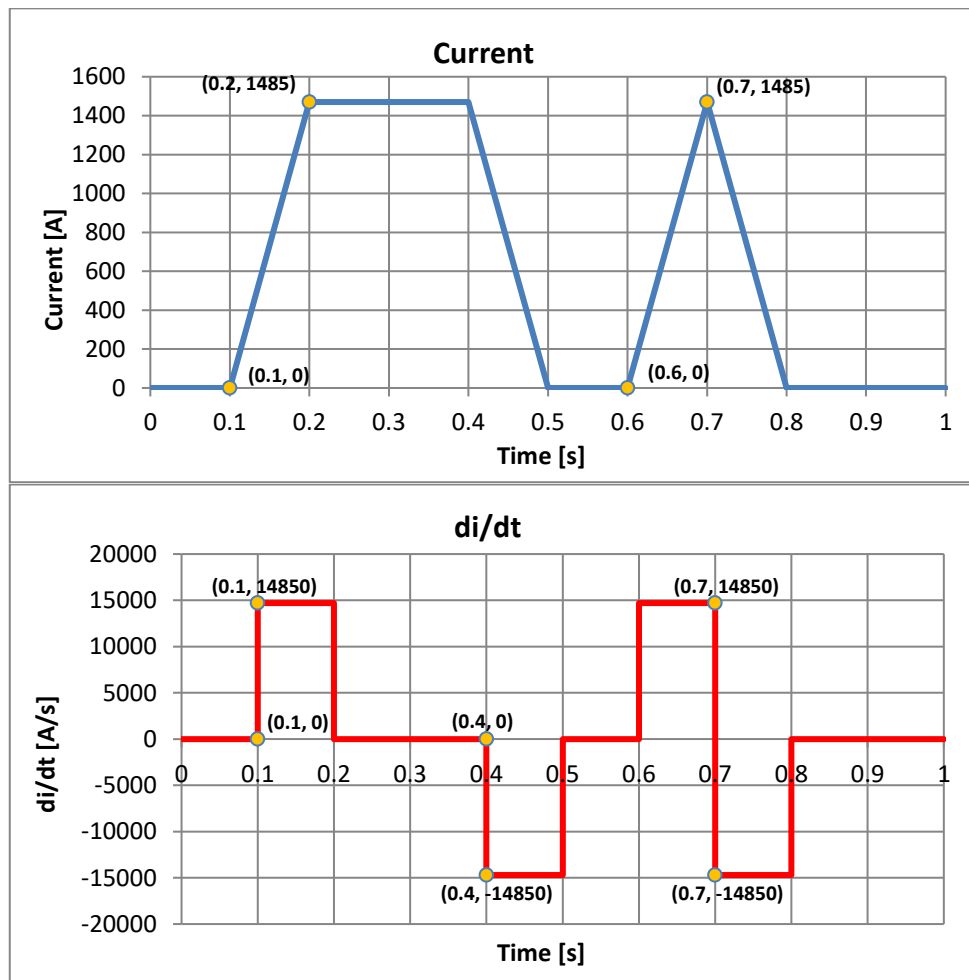
$f_{\text{min}}$  – the smallest existing ripple frequency (depending on the power converter);

$U_{\text{NFTripple}}(f)$  – measured ripple amplitude of frequency  $f$ , normalized to  $f_{\text{min}}$ ;

$L(I)$  given in Table 4-1.

*However, the aim is that the total ripple (amplitude of the sum of the different frequency components is not exceeding the tolerance given by the previous expression).*

4. An example of the PC output current profile can be seen in Figure 3.
5. The maximum bending time, mentioned in Table 4-1, is specified taking into account that the derivatives of the current set value, up to 2nd order, will have no discontinuities.



**Figure 3: Example of a current profile needed for the SIS100 Fast Quadrupole Magnet**

|                                                                                   |                                    |                     |                    |
|-----------------------------------------------------------------------------------|------------------------------------|---------------------|--------------------|
| Configuration Management and Documentation                                        | Document Type                      | Document Number:    | Date<br>18.02.2020 |
|  | <b>Detailed Specification (DS)</b> | F-DS-EPS-en-PC_0022 | Page<br>12 of 17   |

#### 4.2. Electrical Outputs

Four Coaxial cables in parallel will be used to connect the power converter output to the respective load. The cable dimensions are given in Table 4-1.

The principle of the connection of this type of cables is explained in [6].

#### 4.3. Electrical Inputs (Power Part, Control Part)

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 2.5mm<sup>2</sup> 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

Most of the interlocks to be applied are listed in Subsec. 8.5.10 of [2].

To protect the magnet in case of a problem, power converters must include a Free-wheeling Thyristor (FT). Depending on the type of the interlock (see Sec. 4.6), the FT must be activated simultaneously with the PC turn off.

FT shall be provided and installed at the output of the PC by the contractor.

For additional information on the actions to be taken in case of an interlock, see Sec. 4.6.

In addition to that, Beam interlock system (version 'A' in Subsec. 8.5.11 of [2]) have to be foreseen.

The pin assignment is presented in Subsec. 4.3.2 of [4].

#### 4.6. Interaction of the PC with the MPS

The protection of the SIS100 machine is coordinated by the Machine Protection System (MPS).

The PC shall interact with the MPS as described in Table 4-2. These actions must be taken together with what is mentioned in Sec. 4.5 of this document.

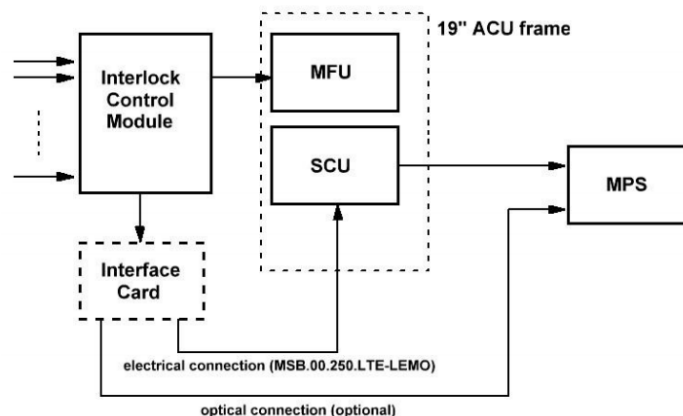
|                                            |                                    |                     |               |
|--------------------------------------------|------------------------------------|---------------------|---------------|
| Configuration Management and Documentation | Document Type                      | Document Number:    | Date          |
| <b>FAIR GSI</b>                            | <b>Detailed Specification (DS)</b> | F-DS-EPS-en-PC_0022 | 18.02.2020    |
|                                            |                                    |                     | Page 13 of 17 |

| Type of Interlock | Free-wheeling through FT | Power Converter (PC) | MPS              |
|-------------------|--------------------------|----------------------|------------------|
| Internal          | Activate                 | Turn off             | Send information |
| External          | Activate                 | Turn off             | Send information |
| δI violation      | -                        | -                    | Send information |

**Table 4-2: Actions to be taken in case of interlock**

The actions described in Table 4-2 will be managed by the ACU system.

An interface card to connect the PC and the MPS will be provided by the Company. In case of an interlock, this card will send the information from the Interlock Control Module of the PC to the MPS (see Figure 4).



**Figure 4: Action diagram during an interlock**

The signal sent from the interface card to the MPS can be either optical or electrical. In any case, it must be taken into account that an electrical signal cable (MSB.00.250.LTE – Lemo), which shall be provided and installed by the contractor, will be connected to the front panel of the ACU Frame (SCU card). This connection will be done by the Company. The integration of the interface card shall be done by the contractor.

The integration of the interface card shall be done by the manufacturer.

Additionally, the current through the FT (mentioned in Sec. 4.5) must be monitored. If the corresponding signal exceeds an adjustable threshold, an interlock have to be produced. This monitoring can be done using AC current transformers, which should be proposed by the manufacturer.

|                                                                                   |                                    |                     |                    |
|-----------------------------------------------------------------------------------|------------------------------------|---------------------|--------------------|
| Configuration Management and Documentation                                        | Document Type                      | Document Number:    | Date<br>18.02.2020 |
|  | <b>Detailed Specification (DS)</b> | F-DS-EPS-en-PC_0022 | Page<br>14 of 17   |

#### 4.7. 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 given in [8].

#### 4.8. Electrical Supply System

All the power parts of the power converters described in this document are going to be fed by the 20 kV/400 V transformer on the feeder PP1 or PP2 (Sec. 2.3 of [3]).

All the electrical interfaces for electronic parts are going to be fed by a 20kV/400V transformer in the common supply system feeder C2 or C3 (Sec. 2.3 in [3]).

#### 4.9. 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].

#### 4.10. 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, Procedures for Construction and Production

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 substitutes 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).

|                                                                                   |                                    |                     |                    |
|-----------------------------------------------------------------------------------|------------------------------------|---------------------|--------------------|
| Configuration Management and Documentation                                        | Document Type                      | Document Number:    | Date<br>18.02.2020 |
|  | <b>Detailed Specification (DS)</b> | F-DS-EPS-en-PC_0022 | Page<br>15 of 17   |

- Production of the systems, FAT and shipping;
- Installation, commissioning and testing at the Company site (SAT).

Monthly status reports are mandatory during all the phases. The deliverables of each phase and the corresponding rights will become 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);

|                                                                                   |                                    |                     |                    |
|-----------------------------------------------------------------------------------|------------------------------------|---------------------|--------------------|
| Configuration Management and Documentation                                        | Document Type                      | Document Number:    | Date<br>18.02.2020 |
|  | <b>Detailed Specification (DS)</b> | F-DS-EPS-en-PC_0022 | Page<br>16 of 17   |

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 operating 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 Subsec. 9.2.1 of [2]. The tests can be performed using a test load.

|                                                                                   |                                    |                     |                    |
|-----------------------------------------------------------------------------------|------------------------------------|---------------------|--------------------|
| Configuration Management and Documentation                                        | Document Type                      | Document Number:    | Date<br>18.02.2020 |
|  | <b>Detailed Specification (DS)</b> | F-DS-EPS-en-PC_0022 | Page<br>17 of 17   |

### 5.3.2. Site Acceptance Test (SAT)

SAT comprises 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. In addition, oppositely to what is mentioned in Section 9.3.1 of [2], during the SAT Ab, the passivating of the cooling system doesn't need to be done. 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. 11.2 of [2]).

## 7. Related Documents

- [1] General Specifications, F-GS-F-01e
- [2] Common Specifications on Power Converters, F-CS-PC-01e
- [3] Electrical Design Rules and Regulations, F-TG-ET-01e
- [4] Integration of ACU for switched mode Power Converters, F-TN-PC-01e
- [5] Component ID and Barcode System, F-TG-B-05e
- [6] Connection of the Coaxial power cables inside power converters, F-TN-PC-02e
- [7] DCCT class 3 Installation in Power Converters, F-TN-PC-0005e

## 8. Attached Documents

- [8] List\_with\_CID\_numbers\_for\_F-DS-EPS-en-PC\_0022\_SIS100\_Power\_Converter\_for\_Fast\_Quadrupole\_Magnet