Accelerator Personnel Safety System 0 and Ion Source Interface Control Document

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1. INTRODUCTION

1.1 Purpose of the document

The Accelerator Personnel Safety System 0 (PSS0) and Ion Source (ISrc) Interface Control Document (ICD) incorporates the definition, documentation, and control of all interfaces between PSS0 and the ISrc. The types of information contained in this ICD include both mechanical and electrical interfaces such as physical footprint, environment temperature, power requirements, connector specification, and electromagnetic compatibility requirements. Also as part of the functional description of PSS0, the impact of PSS0 interfaces on ISrc system operation is defined and described in this document.
This document is created and maintained by the PSS team in cooperation with the system and all the relevant subsystem(s) stakeholder(s) of the ISrc.

Note:
In line with Accelerator systems, Accelerator PSS will be installed and commissioned in stages. The installation and commissioning stages of Accelerator PSS is briefly described below:

- PSS0: It aims to mitigate high voltage electrical hazards for personnel arising from operating the ISrc and LEBT test stand, as described in [1].
- PSS1: It aims to mitigate hazards, as described in [2], for personnel arising from operating the normal conducting section of the accelerator.
- Accelerator PSS: It aims to mitigate hazards for personnel arising from operating the (whole) accelerator, including the super conducting and transport to target areas.

Considering the installation and commissioning phases mentioned above, PSS interfaces with ISrc will be implemented in stages as well. **This document is addressing the PSS0 interfaces with ISrc, and will be valid during the ISrc and LEBT test stand operation**.

The PSS1 and Accelerator PSS interfaces with ISrc are detailed in [3].

1.2 Definitions, acronyms and abbreviations

Abbreviation	Explanation of the abbreviation
Accelerator PSS	Personnel Safety System for complete accelerator
AD	Accelerator Division
ICD	Interface Control Document
ICS	Integrated Control System Division
EMC	Electromagnetic Compatibility
FEB	Front End Building
G01	Accelerator Tunnel Building
HV	High Voltage
HV PS	High Voltage Power Supply
ISrc	Ion Source
LCR	Local Control Room
PLC	Programmable Logic Controller
PSS	Personnel Safety Systems
PSS0	Personnel Safety System for ISrc and LEBT Test Stand
PSS1	Personnel Safety System for Normal Conducting Linac
SIF	Safety Instrumented Function

1.3 REFERENCES

[1] IEC61508 Scope Document for Accelerator personnel Safety System 0
[2] IEC 61508 Scope Document for the Accelerator Personnel Safety System 1
[3] Accelerator Personnel Safety System and Ion Source Interface Control Document (ESS-0064042)
[4] Functional and Technical Description of the Ion Source (ESS- 0088655).
[5] Accelerator Personnel Safety System 0 and Ion Source Interface Control Document (ESS-0237562).
[6] PSS 0 Electrical Circuit Diagram (ESS-0151602)
[7] PSS0 Hardware Design Requirements Specification (ESS-0237967)
[8] IEC61508 Overall Safety Requirements and their Allocation Document for PSS0 (ESS-0231390)
[9] Statement of Work-Supply, Design and Installation of Rack Cabinets (ESS-0085695)
[10] Design Document for Power panel FEB_CNPW_N1U1 (ESS-0091922)
[11] Accelerator FEB Electrical Cable List (ESS-0149816)
[12] Accelerator Personnel Safety System 0 and Ion Source Interface Control Document (ESS-0134492)
[13] PSS0 Software Planning document (ESS-0237557)
[14] Personnel Safety System Configuration Management Plan (ESS-0058389)

2. CHARACTERISTICS OF THE ION SOURCE SYSTEM

2.1 System purpose

The ISrc generates the proton beam through two main functions:

1. Creating the plasma

The plasma is created by a microwave discharge in a chamber filled with H2 gas. The injected RF power comes from the magnetron. The three solenoids create an axial magnetic field that confines the plasma, and optimizes the ion production. The isolation transformer feeds the electrical power necessary for all the equipment sitting on the HV platform, and isolates this environment from ground potential. The equipment on the HV platform includes the magnetron power supply, the solenoid power supplies, and the controls. [4]

2. Extracting the beam

Independent of the plasma generation on the HV platform, the platform is charged to 75 kV by a high voltage power supply. This allows the beam to be extracted and accelerated to 75 keV by the extraction electrodes at ground potential. [4]

2.2 System overview

The ISrc is enclosed in a Faraday cage on a HV platform. The main parts of the ISrc are the plasma chamber surrounded by three solenoids, the magnetron with its waveguide, and the three-electrode extraction system. Figure 1 shows a 3D-model of the HV platform [4].

The ISrc consists of the following systems:

- **A gas delivery system:**

Proton beam will be generated using hydrogen gas injection into the ISrc.

- **A plasma generator:**

The plasma necessary to produce the charged particles will be generated and maintained through the injection of microwaves inside the plasma chamber.

- **An extraction system:**

The beam extraction from the plasma will be ensured by a potential difference between the plasma chamber and the extraction electrodes.

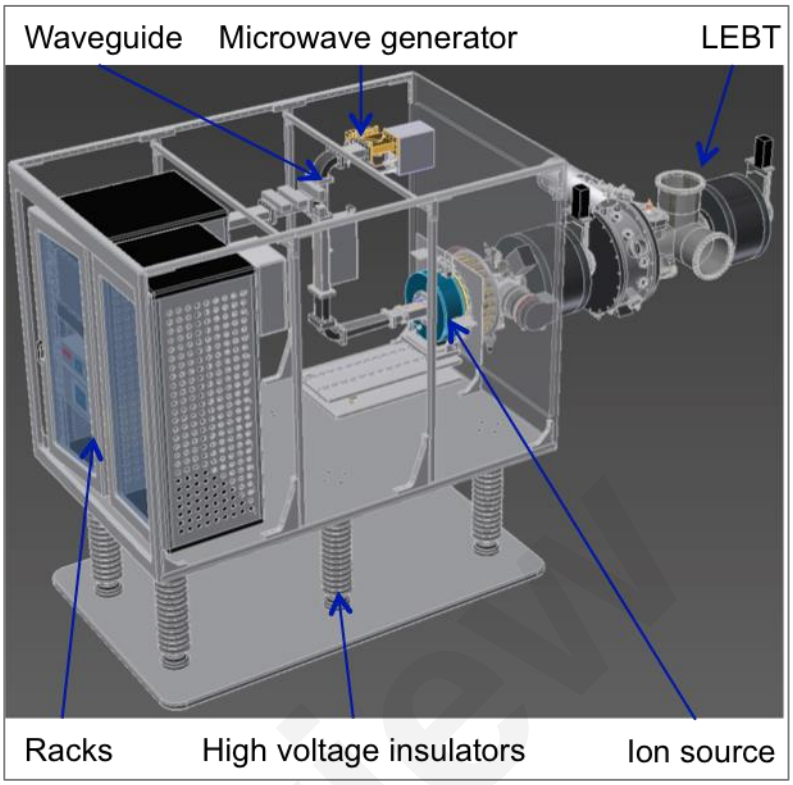

Figure 1: ISrc HV platform

The complete functional and technical description of the accelerator ISrc can be found in [4].

3. ISRC SYSTEM BLOCK DIAGRAM AND PSS0 INTERFACES

According to Accelerator Personnel Safety System 0 and Ion Source Interface Control Document [5], to mitigate electrical hazards for personnel arising from operating the ISrc and LEBT test stand, PSS0 will interface ISrc subsystems, as shown in the block diagram in figure 2.

PSS0 will interface with ISrc equipment as below:

1. ISrc HV PS
- Interfacing the mains incoming power to the HV PS with two contactors in series.
- Interlocking the HV PS through ISrc interlock PLC.

2. ISrc HV platform
- Monitoring the position of HV platform doors with position monitoring switches.
- Grounding relay connecting the HV platform to ground.
- Grounding rod connecting the HV platform to ground.

3. ISrc HV safety fence
- Interface with the ISrc HV safety fence
- Interface with ISrc HV safety fence access door

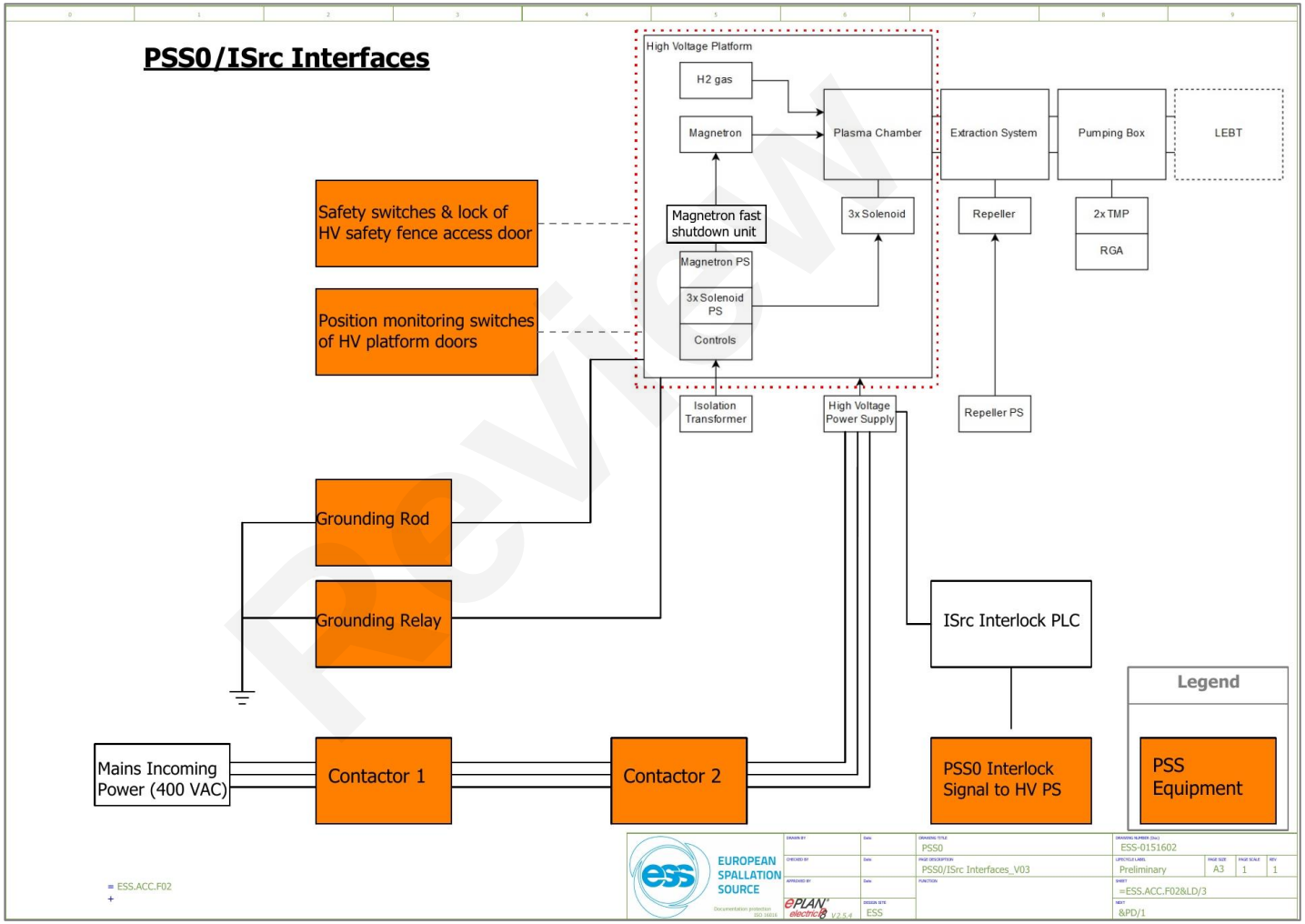

Figure 2: ISrc system block diagram and PSS0 interfaces

4. PSS0 INTERFACES WITH THE ISRC HV PS

4.1 Interface with the mains incoming power to the HV PS

According to the Functional and Technical Description of the Ion Source document [4], the ISrc platform is charged to 75 keV by a 20 KVA high voltage power supply (ISrc-010:ISS-HVPS) which allows the beam to be extracted and accelerated to 75 keV. The ISrc HV PS is installed in G01-FEB-level 090 building. PSS0 will interface the ISrc HV PS by installing two contactors in series on the 3-phase mains power cable feeding the ISrc HV PS.

The technical data of Siemens contactor relays and contactors to be used for PSS0 interface with ISrc HV PS is as below:

- Siemens contactor relay, DC 24V, 2NO+2NC, 4-Pole, Size S00 with Integrated Diode, Screw Connection (product number: 3RH2122-1FB40). See figure 3 for more details.
- Siemens contactor, AC-3 30 kW/400 V, DC 24V, 2 NO + 2 NC, 3-Pole, Size S3, Screw Connection (product number: 3RT1044-1BB44). See figure 4 for more details.

product brand name	SIRIUS
Product designation	contactor relay
General technical data:	
Size of contactor	S00
Product extension	
• Auxiliary switch	Yes
Insulation voltage	
• with degree of pollution 3 rated value	690 V
Degree of pollution	3
Surge voltage resistance rated value	6 kV
Protection class IP	
• on the front	IP20
Shock resistance	
• at rectangular impulse	
— at DC	10g / 5 ms, 5g / 10 ms
• with sine pulse	
— at DC	15g / 5 ms, 8g / 10 ms
Mechanical service life (switching cycles)	
• of contactor typical	30 000 000
• of the contactor with added electronics-compatible auxiliary switch block typical	5 000 000
• of the contactor with added auxiliary switch block typical	10 000 000
Equipment marking	
• acc. to DIN EN 61346-2	K
• acc. to DIN EN 81346-2	K

Figure 3: Technical data of the PSS0 contactor relays

product brand name	SIRIUS
Product designation	power contactor
General technical data:	
Size of contactor	S3
Insulation voltage	
• rated value	1 000 V
Degree of pollution	3
Surge voltage resistance rated value	6 kV
maximum permissible voltage for safe isolation	
• between coil and main contacts acc. to EN 60947-1	690 V
Protection class IP	
• on the front	IP00
• of the terminal	IP00
Shock resistance	
• at rectangular impulse	
— at DC	6,8g / 5 ms, 4g / 10 ms
• with sine pulse	
— at DC	10,6g / 5 ms, 6,2g / 10 ms
Mechanical service life (switching cycles)	
• of contactor typical	10 000 000
• of the contactor with added electronics-compatible auxiliary switch block typical	5 000 000
• of the contactor with added auxiliary switch block typical	10 000 000
Ambient conditions:	
Installation altitude at height above sea level maximum	2 000 m
Ambient temperature	
• during operation	-25 ... +60 °C
• during storage	-55 ... +80 °C
Main circuit:	
Number of NO contacts for main contacts	3
Number of NC contacts for main contacts	0
Operating current	
• at AC-1 at 400 V	
— at ambient temperature 40 °C rated value	100 A
• at AC-1 up to 690 V	
— at ambient temperature 40 °C rated value	100 A
— at ambient temperature 60 °C rated value	90 A
• at AC-3	
— at 400 V rated value	65 A
— at 690 V rated value	47 A

Figure 4: Technical data of the PSS0 contactors

4.2 Interface with the ISrc interlock PLC

The interface between PSS0 and ISrc interlock PLC will be through hardwired signals. Dry contacts will be used in interface points between ISrc interlock PLC and PSS0 PLC.

The signal list is as below:

- ISrc HV PS Permit: PSS0 permit for HV PS interlock relay (PSS0 permits Interlock PLC to enable/disable the HV PS through HV PS interlock relay). The PSS permit for HV PS should be shown on the GUI in the local control room (LCR).
- PSS OK: PSS0 status in local control room (PSS0 sends its status to Interlock PLC to be shown on the GUI in local control room).

The cable names and types for signals are detailed in PSS 0 Electrical Circuit Diagram [6].

4.3 Wiring Diagram of PSS0 Interface with ISrc HV PS

PSS0 will interlock the 3-phase mains power to the ISrc HV PS. In order to de-energize ISrc HV PS, the 3-phase mains power of the ISrc HV PS must pass through the two PSS contactors (in series) which are installed in a PSS enclosure in G01-FEB Level 90 (FEB-010ROW:CNPW-U-007).
According to the PSS0 Electrical Circuit Diagram [6], the two PSS0 contactor relays operations are independent from each other (i.e. each PSS0 contactor relay is controlled by one of the PSS0 trains)[7].
The wiring diagram for the remote-tripping function of the PSS0 contactor relays and the two PSS0 contactors interfacing the 3-phase mains power to ISrc HV PS is shown in figure 5.
In order to achieve the required Safety Integrity Level (SIL) for PSS SIFs [8] which use ISrc HV PS as EUC to remove electrical hazard, each PSS0 train uses two contactors (in series) to interlock ISrc HV PS. Since there is not a contactor available on the market, that has two control coils, PSS0 will use a contactor relay in each train, which provides the possibility for each PSS0 train to disable both contactors (open power contacts) at any time. The contactor relays also prevent damage to PLC failsafe output modules caused by the closing power of contactors' magnet coils.
Therefore, each of the PSS0 trains will control and monitor both contactors, which supply mains power to ISrc HV PS.

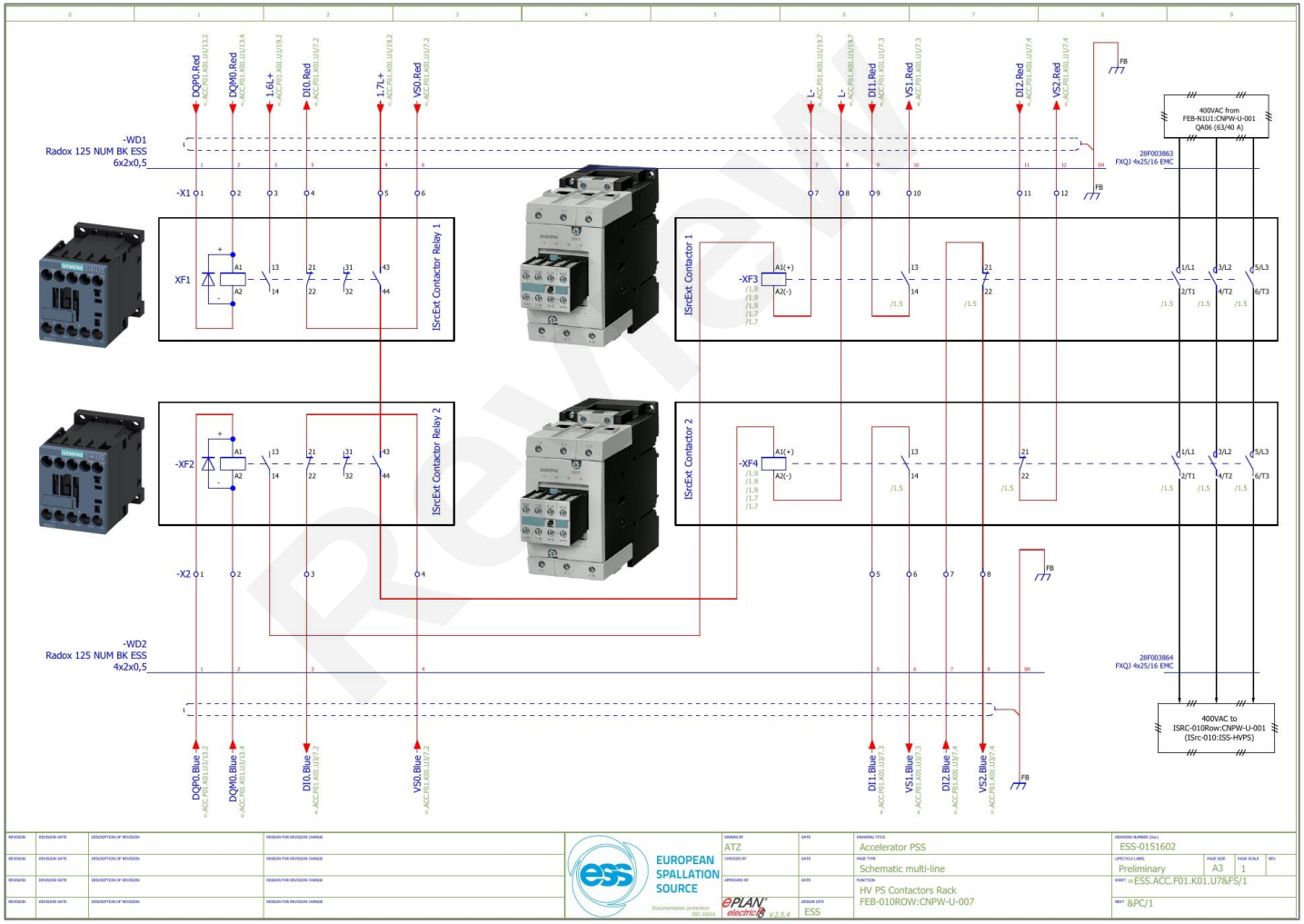

Figure 5: PSS0 contactors interfacing the 3-phase mains power to ISrc HV PS

4.4 Enclosure for ISrc HV PS PSS0 contactors

According to the PSS0 Electrical Circuit Diagram [6], the PSS0 contactor relays and contactors (for both PSS0 trains) are installed in a PSS0 enclosure in G01-FEB-level 090 (FEB-010ROW:CNPW-U-007).

The 3D model view of the PSS enclosure housing the contactor relays and contactors for PSS0 interface with ISrc HV PS is shown in figure 6.

Figure 6: Enclosure for ISrc HV PS PSS0 Contactors

- The PSS0 contactor relays, contactors and terminals which are directly connected to PSS PLC I/O modules will be installed in the front side of the mounting plate.
- The ambient temperature of the area where contactor relays and contactors are installed should be according to technical data shown in figure 4.
- The enclosure housing the contactor relays and contactors for PSS0 interface with ISrc HV PS is of EMC type.
- The PSS0 rack is painted in RAL2000.
- The specification for PSS racks can be found in Statement of Work-Supply, Design and Installation of Rack Cabinets document [9].

4.5 Cables and cable routes

- The mains power to the ISrc HV PS is supplied by QA06 three-pole circuit breaker (63/40 A) installed in FEB-N1U1:CNPW-U-001 rack in G01-FEB-level 090 [10].
- The mains power cable for the ISrc HV PS (cable name: 28F003863) will be connected from FEB-N1U1:CNPW-U-001 rack to PSS0 enclosure (FEB-010ROW:CNPW-U-007).
  The cable route is **ESS.INFR.U02.U01.U15.U0074 -> U0068 -> U0082 -> U0067**. [11]
  The mains power cable for the ISrc HV PS (cable name: 28F003864) will be connected from PSS0 enclosure (FEB-010ROW:CNPW-U-007) to ISrc HV PS rack (ISRC-010Row:CNPW-U-001).

The cable route is **ESS.INFR.U02.U01.U15.U0067 -> U0080 -> U0075 -> U0072**. [11]

5. PSS0 INTERFACES WITH ISRC HV PLATFORM

5.1 High voltage grounding relay

According to the PSS0 concept of operations [12], following the opening of two contactors interfacing with the mains incoming power to ISrc HV PS, a grounding relay should connect the ISrc HV platform to ground in order to ensure that the stored energy in ISrc HV PS capacitors and output cable will be discharged.

Based on the power rating of the ISrc HV PS [75 kV DC nominal (100 kV max.) and 150 mA (max.)], a 120 kV DC grounding relay will be installed to connect the ISrc HV PS to ground when there is access to PSS0 controlled area. The grounding relay product number is ED120-NC-120-2-31-BD, and its specifications are shown in figure 7:

SPECIFICATIONS **760MMHg 20°C AMBIENT**

RELAY MODEL	CON-TACT FORM	1 MINUTE PK TEST RATING DC OR AC PK		* CURRENT RATINGS NEW & DUST FREE			MAX CONTACT RESIS-TANCE NEW & CLEAN	OPERATE TIME MAX MILLI-SEC	RE-LEASE TIME MAX MILLI-SEC	** STANDARD 115V, 60Hz COIL	
		HV CONTACTS	INSULATION TO GROUND	CONTINUOUS AMPS RMS	MOMENTARY 10 CYCLE AMPS RMS	MOMENTARY CAPACITOR DIS-CHARGE, 20 uSEC				MAX RMS INRUSH CURRENT	MAX RMS HOLD CURRENT
ED120-NC	SPNC	120KV	120KV	200A	2,000A	10,000A	.0005Ω	120	180	*** 35A	2A

Figure 7: Grounding relay specifications

The high voltage grounding relay will be installed within the PSS0 controlled area. Figure 8 shows the location of the PSS0 high voltage grounding relay. The grounding cable, interfaced by the grounding relay, will be bolted to the ISrc HV platform on one side, and will be connected to the grounding plate on the other side.

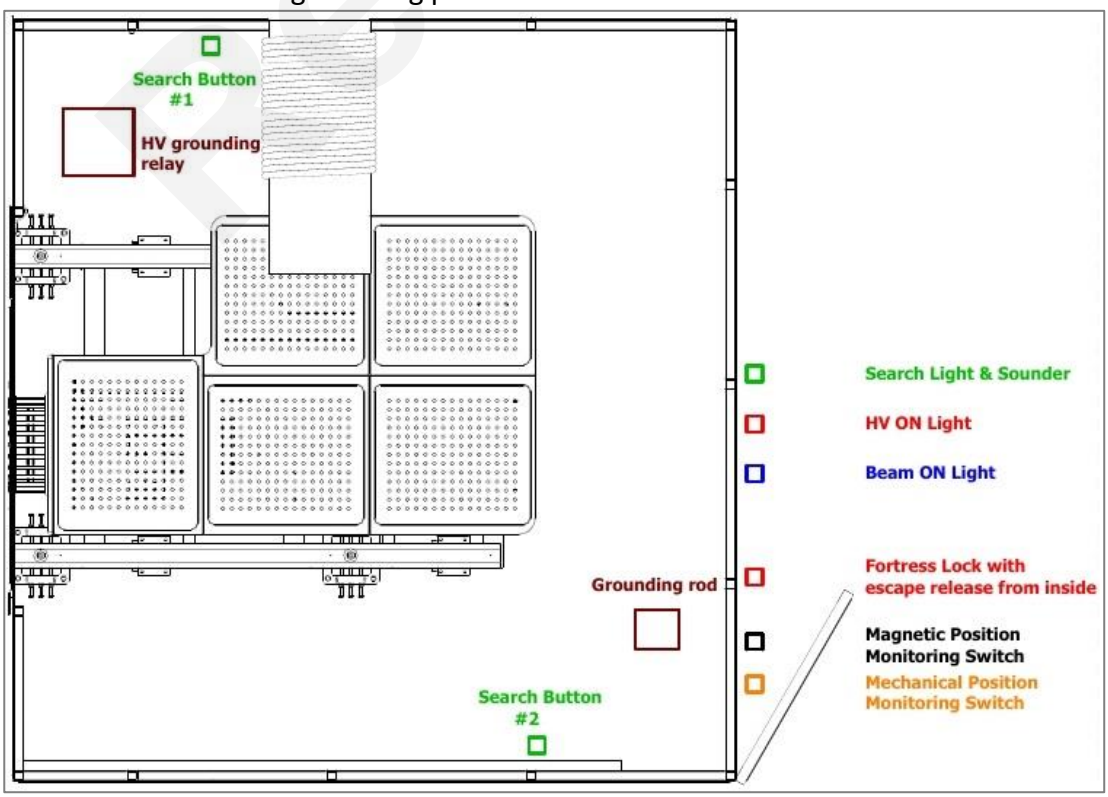

Figure 8: PSS0 equipment location in/outside PSS0 controlled area

5.2 Wiring Diagram of PSS0 grounding relay

PSS0 will interlock the high voltage grounding relay.
The wiring diagram for the remote-tripping function of the PSS0 grounding relay is shown in figure 10.

5.3 Grounding rod

According to the PSS0 concept of operations [12], following the opening of two contactors interfacing with the mains incoming power to ISrc HV PS and upon access of the authorized person to PSS0 controlled area, a grounding rod shall be placed at the ISrc HV platform.

- The grounding rod will be installed across the access door to PSS0 controlled area. The grounding rod will be equipped with micro-switches which confirm that it is placed in its rest position prior to energizing the ISrc HV PS.
- An eye bolt on the ISrc HV platform (according to figure 9) will be used to connect the grounding rod to HV platform.

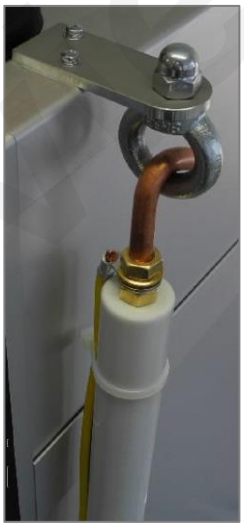

Figure 9: Grounding rod connection to HV platform

5.4 Position monitoring switches of the HV platform doors

There will be position monitoring switches on all doors of the ISrc HV platform. The micro switches will be connected to the PSS0 remote PLC I/Os installed in a small rack on the ISrc HV platform.

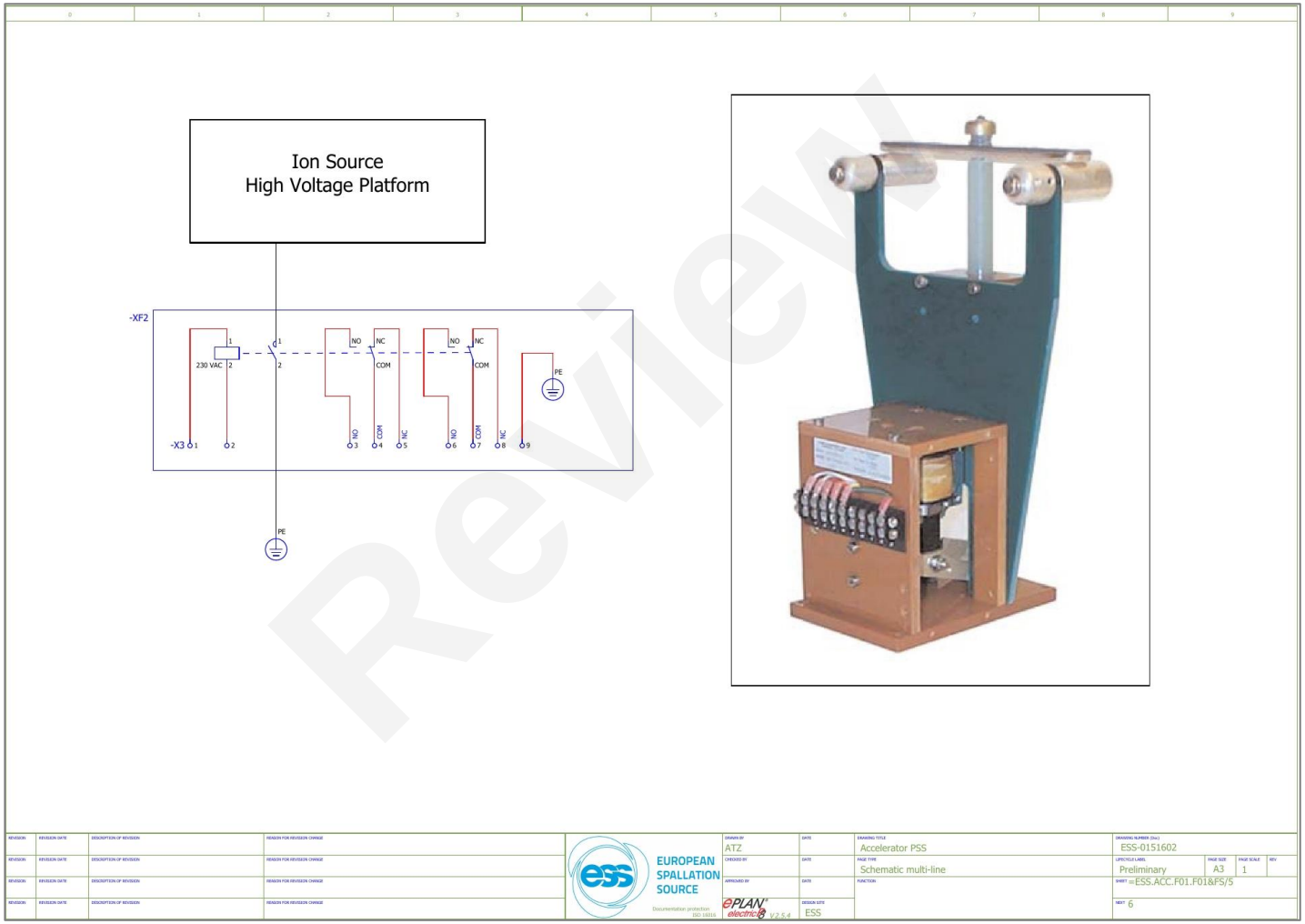

Figure 10: Grounding relay connection to ISrc HV platform

6. PSS0 INTERFACES WITH THE ISRC HV SAFETY FENCE

6.1 Interface with the ISrc HV safety fence

PSS0 equipment will be installed on various parts of ISrc HV safety fence, as detailed below.

- Search buttons (2 off) to be installed on the inner side of HV safety fence.
- PSS0 lights and sounder (as mentioned below) to be installed on the outer side of HV safety fence:
    - Light and sounder for search process.
    - Light for “HV ON” signalization.
    - Light for “Beam ON” signalization.

6.2 Interface with ISrc HV safety fence access door

- There is only one access door to the PSS0 controlled area, and PSS0 will monitor the position (open/closed) of the access door, using two safety switches with different technology.
    - Mechanical safety switch with separate actuator
    - Non-contact magnetically operated safety switch

Figure 11 shows PSS0 safety switches.

Figure 11: From left to right: Mechanical safety switch; Magnetic safety switch; Fortress lock

- The access door to the PSS0 controlled area will be locked by a Fortress safety lock which will be controlled by PSS0. The Fortress lock is equipped with a mechanical escape release from inside to be used in case of emergency escape from PSS0 controlled area. Figure 11 shows PSS0 Fortress lock.

Figure 8 shows the location of PSS0 equipment in PSS0 controlled area.
The mechanical and electrical details of all PSS0 interfaces with ISrc equipment can be found in [6].

7. OPERATING MODES

The different operational modes for PSS0 and their impact on ISrc HV PS operation is described in table 1.

Table 1: PSS0 operating modes description of impact on ISrc HV PS operation

PSS0 Mode	Mode Description
HV ON	In this mode the HV PS is enabled by PSS0; - PSS0 controlled area is searched and access door is locked. - The contactors interfacing the mains power to ISrc HV PS are closed (enabled). - The grounding relay is open. - The grounding rod is removed from ISrc HV platform. - PSS0 permit signal to ISrc interlock PLC (to enable HV PS) is ON.
SEARCH	In this mode the HV PS is disabled by PSS0; - PSS0 controlled area is being searched. - The contactors interfacing the mains power to ISrc HV PS are open (disabled). - The grounding relay is closed. - PSS0 permit signal to ISrc interlock PLC (to enable HV PS) is OFF.
ACCESS	In this mode the HV PS is disabled by PSS0; - PSS0 controlled area can be accessed by authorized personnel. - The contactors interfacing the mains power to ISrc HV PS are open (disabled). - The grounding relay is closed. - The grounding rod is placed at ISrc HV platform. - PSS0 permit signal to ISrc interlock PLC (to enable HV PS) is OFF.
ALARM	PSS0 will transition to this mode when emergency situations (for e.g. intrusion into PSS0 controlled area, E-stop button pressed, PLC module(s) and PSS0 equipment failure, etc.) happen. In this mode the HV PS is disabled by PSS0; - Access to PSS0 controlled area may not be prohibited by PSS0. **However, personnel shall follow instructions issued by operation manager to access the PSS0 controlled area.** - The contactors interfacing the mains power to ISrc HV PS are open (disabled). - The grounding relay is closed. - PSS0 permit signal to ISrc interlock PLC (to enable HV PS) is OFF.

The PSS0 operating modes are elaborated in PSS0 Software Planning document [13].

Notes:

- As part of PSS0 operation, before any access to the PSS0 controlled area, PSS0 requires to turn off the ISrc HV through PSS0 interfaces.
  In order to prevent the hard shut down of ISrc HV PS, before PSS0 moves from HV ON mode to Access or Alarm modes, PSS0 will disable the permit signal to ISrc interlock PLC.

8. RESPONSIBILITIES

1. AD will be responsible to provide and install the following items:

- Provide, install and terminate the mains power cable and the required cable lugs, cable trays and cable markers [from distribution board (FEB-N1U1:CNPW-U-001) through PSS0 enclosure to ISrc HV PS].

2. ICS will be responsible to provide and install the following items:

- Provide and install contactor relays and contactors required for the interface.
- The enclosure to house the contactor relays and contactors.
- The cable and cable trunks for control signals from PSS0 distributed I/O enclosures to the PSS0 enclosure for ISrc HV PS contactors.
- Test, verify, and validate the PSS0 interfaces with ISrc HV PS during PSS0 commissioning, validation and annual (if applicable) tests.

9. SAFETY

The access, maintenance and any modification to PSS0 enclosures for ISrc HV PS contactors (FEB-010ROW:CNPW-U-007) during any mode of PSS0 operation shall only be done by authorized PSS personnel.

10. CONFIGURATION MANAGEMENT

As stated earlier in this document, this ICD document is addressing the PSS0 interfaces with ISrc, and will be valid during the ISrc and LEBT test stand operation. Any change in this document, by any of the stakeholders shall follow the change management procedure according to Personnel Safety System Configuration Management Plan document [14].

DOCUMENT REVISION HISTORY

Revision	Reason for and description of change	Author	Date
1	First issue	Morteza Mansouri	2018-02-02