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## PSS0 Hardware Design Requirements Specifications

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	Name	Role/Title
<b>Owner</b>	Morteza Mansouri	Engineer for Safety Critical Systems, ICS
<b>Reviewer</b>	Stuart Birch Annika Nordt	Senior Engineer for Personnel Safety Systems, ICS Protection and Safety Systems Group Leader, ICS
<b>Approver</b>	Timo Korhonen	Chief Engineer, ICS

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## 1. INTRODUCTION

### 1.1 Purpose of the document

This document provides an overall hardware design requirement specification for the Accelerator Personnel Safety System 0 (PSS0) at European Spallation Source ERIC in Lund, Sweden. The objective is to define and set out the specific and detailed requirements for the PSS0 in terms of its hardware requirements.

### 1.2 Definitions, acronyms and abbreviations

Abbreviation	Explanation of the abbreviation
AD	Accelerator Division
ICS	Integrated Control System Division
CPU	Central Processing Unit
EMC	Electromagnetic Compatibility
EMI	Electromagnetic interference
FEB	Front End Building
G01	Accelerator Tunnel Building
HMI	Human Machine Interface
HV	High Voltage
HV PS	High Voltage Power Supply
ISrc	Ion Source
PLC	Programmable Logic Controller
PSS	Personnel Safety Systems
PSS0	Personnel Safety System for ISrc and LEBT Test Stand
SPD	Surge Protection Device.
UPS	Uninterruptible Power Supply

### 1.3 REFERENCES

- [1] PSS 0 Electrical Circuit Diagram (ESS-0151602)
- [2] Concept of Operations For the Accelerator Personnel Safety System 0 (PSS0) (ESS-0134492)
- [3] Accelerator Personnel Safety System 0 and Ion Source Interface Control Document (ESS-0237562)
- [4] Accelerator FEB Electrical Cable List (ESS-0149816)

## 1 PSSO ARCHITECTURE

### 1.1. Network architecture

PSSO aims to mitigate electrical hazard arising from ISrc and LEBT test stand operation. Therefore, implementing the requirements of Swedish Radiation Safety Authority (SSM) is not necessary to be considered in PSSO design. However, for test purposes and further evaluation, PSSO will be built using two identical Siemens PLC and distributed I/O system with redundant sensors and actuators. This is also known as “two train system”; distinguished as “red train” and “blue train”.

Figure 1 shows the network architecture of PSSO. PSSO network architecture can be found in appendix 1 of this document too.

### 1.2. Physical topology

PSSO network is built on a hybrid topology where there is a ring backbone connecting all PSSO racks. The nodes (PLC CPU and Distributed I/O modules) are connected to this backbone ring in a bus topology. The ring fibre optic backbone will be routed in separated cable routes dedicated to PSSO. The main advantage of this setup is the redundancy in FO cable connection and as a result higher reliability of the system.

PSSO backbone network will be built using single mode fibre optic cables.

The PSSO physical topology and FO cable connector types are shown in figure 2. PSSO physical topology can be found in appendix 2 of this document too.

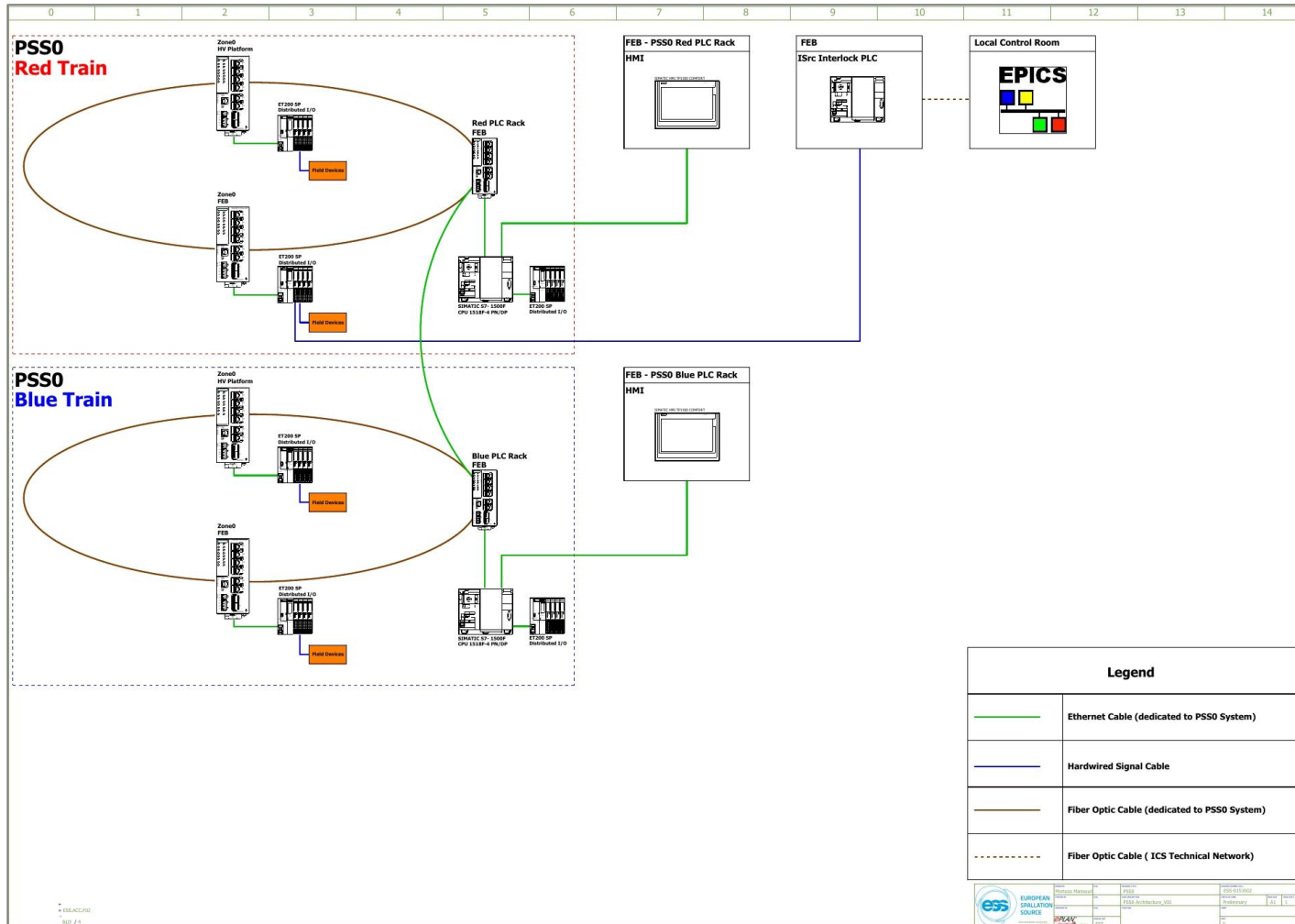


Figure 1: PSS0 network architecture

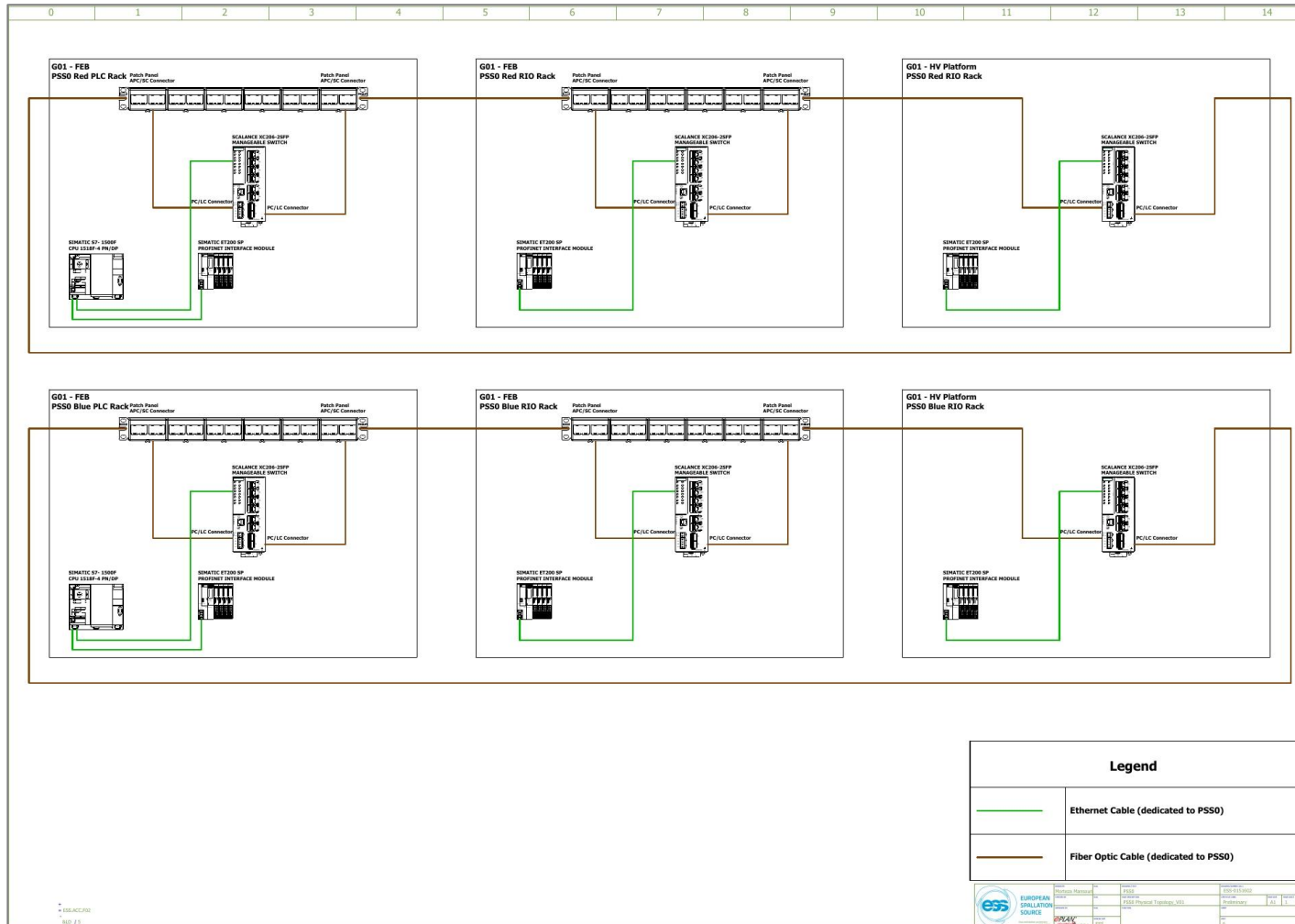


Figure 2:PSS0 physical topology

## 2 PSSO HARDWARE DESCRIPTION

### 2.1 General layout

The PSSO racks will be installed in G01-FEB-Level 90 and also ISrc HV platform in G01-accelerator tunnel. The PSSO field devices are installed in G01-FEB-Level 90, ISrc HV safety fence, and ISrc HV platform.

Figure 3 shows the general layout of PSSO racks and field devices in accelerator building.

### 2.2 PSSO racks and equipment

#### 2.2.1 PSSO rack design

The main system components will be housed in a Pentair (Schroff, Varistar type) steel floor standing double door enclosure. All PLC modules and relays are in front side and all field devices termination are in the rear side. Both doors are to be lockable with a standard Schroff lock. The ambient conditions at the G01-FEB-Level90, where the PSSO racks are installed is as below:

- Room temperature: minimum +10°C
- Humidity: Max 70% RH

The detailed specifications of PSS racks can be found in table 1.

**Table 1: PSS racks specifications**

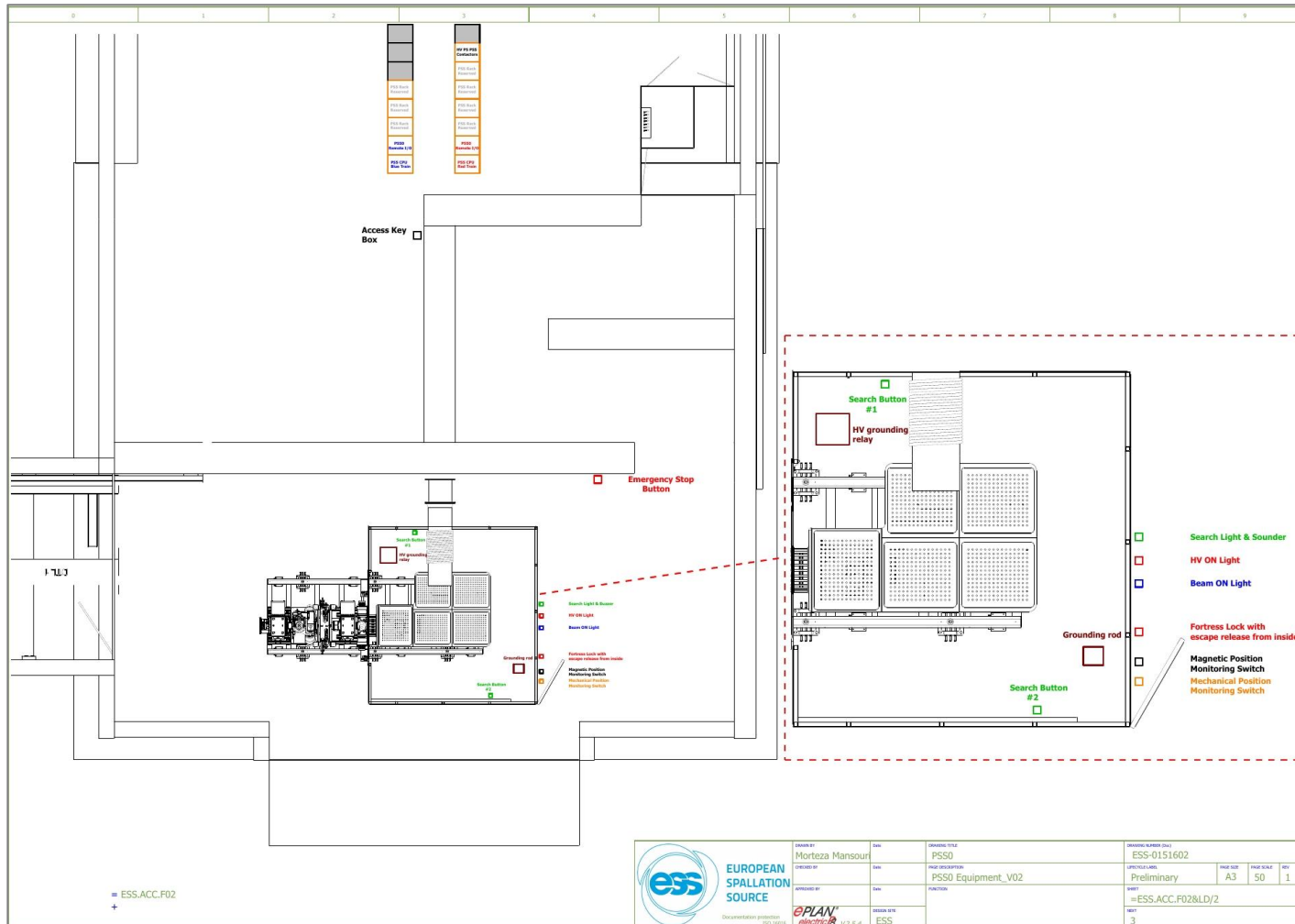
Material	Steel frame and steel cladding
Type of Protection [IP]	IP 55 (IEC 60529)
Height x Width x Depth [mm]	2200 x 600 x 1000
EMC shielding	60 dB at 1 GHz, 40 dB at 3 GHz (IEC 61587-3)
Static load-carrying capacity [kg]	400 (IEC 61587-1)
Shock test	Maximum acceleration: 5 g Duration: 11 ms (IEC 61587-1)
Vibration test	Frequency: 5 Hz -100 Hz Acceleration: 1 g (IEC 61587-1)
Cooling	Air cooled (3 fans on top cover as air outlet, and front half-perforated door with dust filter as air inlet).
Colour	RAL 2000
Components installing options	Mounting plate (2 off) and 19"

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The 2D panel layout of the PSS racks can be found in PSS0 Electrical Circuit Diagram document [1].





**Figure 3: PSSO general layout**

### 2.2.2 Cable entries

The enclosure is designed for top cable entry. Cable entry will be non-glanded and will be designed so that cables will go directly from the cable containment to the enclosure via a sliding plated opening on top of the enclosure. The cable containment will be attached to the enclosure top to keep the EMC integrity of the cables containment. The cable containment installation on top of PSS enclosure and sliding openings for cable entry are shown in figure 1.

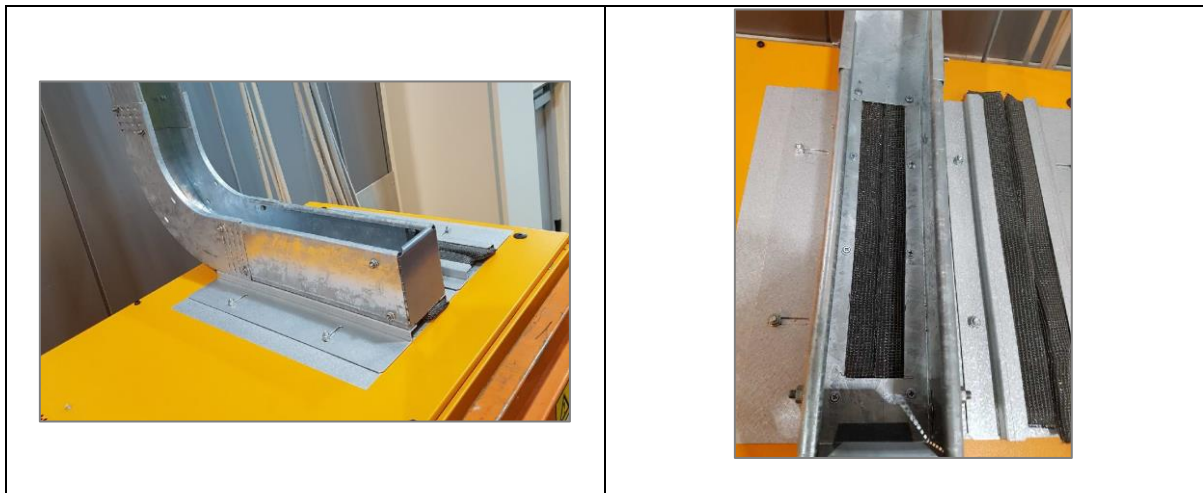


Figure 4: From left to right: Cable containment fixed to PSS enclosure; sliding cable entry

### 2.2.3 Field cable terminations

I/O signal cables are to be terminated to terminal blocks on the rear mounting plate of the PSS enclosures. The terminal blocks specifications are as below:

- Knife disconnect terminal block
- Nominal voltage: 400 V, nominal current: 20 A
- Connection method: Push-in connection

Power supplies to field equipment rated at 230Vac will be connected to terminals located close to the relevant MCB.

### 2.2.4 Grounding

A grounding bar is provided for terminating the incoming ground wire, grounding all field cables screens, panel metalwork and internal equipment.

### 2.2.5 Power distribution

The PSS enclosures will be provided with 230Vac supply. The supply configuration is TN-S, i.e. a separate neutral and earth conductor.

- The 230Vac supply will be fed to the enclosure isolator switch. The OFF state of the isolator switch ensures no low voltage (230 Vac) within PSS enclosure remains live. The 230 Vac will be distributed to other equipment within enclosure through a 6KA, 1+N-POLE, C, 16A Miniature Circuit Breaker (MCB). In order to prevent highly destructive energy from lightning and/or overvoltage generated by operations or incidents on the electrical network, a type 3 (T3) surge arrester (Surge Protection Device) will be installed in each of PSS enclosures.
- 24 Vdc is internally provided in the PSS0 enclosures for most of the PSS0 equipment and field devices (other than HV grounding relay).  
All PSS0 rack are equipped with a UPS and battery. The acquired benefits of having PSS0 backed up with UPS power are as below:
  - o Not losing the searched state of the PSS0 controlled area in case of AC power failure.
  - o Keep monitoring the status of all PSS0 equipment (for about an hour) during AC power failure.

**Siemens SITOP Selection Tool** has been used to select the power supply and also find the matching uninterruptible power supply (DC UPS) based on battery technology for PSS0 racks.

The inputs to the tool and the results are as below:

- **Requested values for each PSS0 rack:**
  - o Buffer time: 60 min
  - o Nominal current: 6 A
  - o Minimal buffer voltage: 21.53 V
- **Result:**
  - o Power Supply : SITOP PSU100S 24 V/10 A
  - o DC UPS with batteries:
    - UPS: SITOP UPS1600 24V/10A
    - Battery : SITOP UPS1100 BATTERY MODULE WITH SERVICE- FREE SEALED LEAD BATTERIES FOR SITOP DC-UPS-MODULES 24 V 12 AH DC
- **Performance Characteristics:**
  - o Buffer time at requested values:
    - brand-new: 1 h 1 min
    - at end of lifetime : 19 min 20 s
    - Reload time after discharge : 3 h 31 min
  - o Lifetime of accumulator (app.):
    - at 20 °C 4 years
    - at 30 °C 2 years
    - at 40 °C 1 years
    - at 50 °C 0.5 years

The details of powering scheme in each PSS0 enclosure is shown in details in PSS0 Electrical Circuit Diagrams document [1].

## 2.2.6 PLC modules

PSS0 will be built using Siemens Safety PLCs (S7-1518 F CPU). Siemens fail-safe CPUs allow the processing of standard and safety programs on a single CPU. The Siemens Safety PLCs are certified to satisfy the Safety Integrity Level SIL3 in accordance with IEC 61508:2010.

The filed PSS0 field devices are controlled through Siemens ET 200 SP standard and safety Distributed I/O modules. The ET 200 SP interface modules connect the I/O system to PSS0 PROFINET network and exchange data between the higher-level controller and the I/O modules. With the SIMATIC ET 200SP, safety-related communication is also possible via PROFIsafe.

The following PLC modules have been tested in PSS test stand, and will be used for PSS0.

- CPU: SIMATIC S7-1500F, CPU 1518F-4 PN/DP (6ES7518-4FP00-0AB0)
- Interface module: PROFINET INTERFACE MODULE ET 200SP IM155-6PN (6ES7155-6AU00-0CN0)
- Digital Inputs:
  - o SIMATIC ET 200SP, DIGITAL INPUT MODULE, DI 16X 24VDC STANDARD (6ES7131-6BH00-0BA0).
  - o SIMATIC DP, ELECTRON. MODULE F. ET 200SP, F-DI 8X24VDC HF, UP TO SIL 3 (6ES7136-6BA00-0CA0)
- Digital Output modules:
  - o SIMATIC ET 200SP, DIGITAL OUTPUT MODULE, DQ 16X24VDC/0.5A STANDARD (6ES7132-6BH00-0BA0)
  - o SIMATIC DP, ELECTRON. MODULE for ET 200SP, F-DQ 4X24VDC/2A, UP TO SIL 3 (6ES7136-6DB00-0CA0)

## 2.2.7 Network communication modules

As shown in PSS0 network architecture (chapter x) and PSS0 physical topology, a Siemens network switch will be used in PSS0. The switch specifications is as below:

- SCALANCE XC206-2SFP manageable layer 2 IE Switch
- 6x 10/100 MBit/s RJ45 ports; 2x 100/1000 MBit/s SFP; 1x console port
- PROFINET IO Device; Ethernet/IP compliance

The switch product number is 6GK5206-2BS00-2AC2.

## 2.2.8 PSS HMI

The two PSS0 enclosures housing the PLC CPUs have SIMATIC HMI Comfort Panels mounted on the front door of the enclosures.

## 2.3 Field devices

### 2.3.1 Grounding and short-circuiting equipment

#### - HV grounding relay

A grounding relay will be installed within PSS0 controlled area to 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 in a safe way.

The power rating of the ISrc HV PS is 75 kV DC nominal (100 kV max.) and 150 mA (max.). The peak test rating of high voltage grounding relay is 1.2 times the normal ISrc HV PS max. output voltage, i.e. the peak test rating of HV grounding relay is 120 kVdc.

The HV grounding relay is a Ross Engineering product (product number: ED120-NC-120-2-31-BD). The grounding relay type is Gravity Return, Mount Base Down.

Figure 5 shows the HV grounding relay, and figure 6 shows the grounding relay specifications in details.



Figure 5: PSS0 HV grounding relay

SPECIFICATIONS							760MMHg 20°C AMBIENT				
RELAY MODEL	CONTACT FORM	1 MINUTE PK TEST RATING DC OR AC PK		* CURRENT RATINGS NEW & DUST FREE			MAX CONTACT RESISTANCE 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 DISCHARGE 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 6: HV grounding relay specifications

- Grounding rod

According to the PSSO concept of operations [2], following the opening of two contactors interfacing with the mains incoming power to ISrc HV PS and upon access of the authorized person to PSSO controlled area, a grounding rod shall be hooked to the ISrc HV platform.

In addition to the HV grounding relay, a grounding by Ross Engineering will be used to temporarily ground or discharge any stored energy in the ISrc HV PS capacitors or output cable. The grounding rod product number is ACC1-8WHH-20-A-8.

The grounding rod includes a holder with interlock micro-switches, which will be installed next to the access door to PSSO controlled area. The micro-switches, connected to PSSO, ensure that the grounding rod is removed from the ISrc HV platform prior to PSSO permit to energize the ISrc HV PS.

Figure 7 shows the grounding rod.



**Figure 7: Grounding rod**

### **2.3.2 Search equipment**

- Illuminated search buttons

There will be search buttons (2 off) which be used during the formalized search of PSSO controlled area. Search buttons will be placed at strategic locations around the PSSO controlled area. Figure 3 shows the location of the search buttons.

These are non-latching illuminated push buttons with a metallic body installed in a plastic cubic body. Each search button will contain 2 NO contacts and 1 green LED unit.

- Search light and sounder

A Siemens signal column will be installed on the outer side of HV safety fence. The signal column includes a green LED light and a sounder. The light and sounder will be used to provide information to the operators and personnel about the search sequences during the formalized search of PSSO controlled area.

Figure 8 shows the signal column to be installed on the outer side of the ISrc HV safety fence.

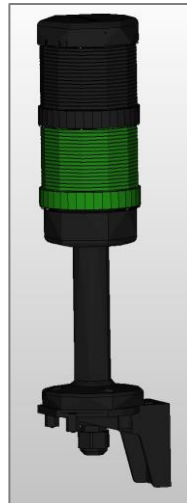


Figure 8: Signal column; search light and sounder

### 2.3.3 Emergency stop button

A single emergency stop (E-stop) button will be installed outside the PSS0 controlled area. Figure 3 shows the location of the E-stop button.

The E-stop is a latching illuminated emergency stop push buttons with a metallic body and mushroom twist-to-release head. The E-stop button will be installed surface-mount on a metallic enclosure. The E-stop button will contain 4 NC contacts and 1 red LED unit and have a protective metal guard to prevent them being pressed accidentally.

2 NC contacts of the E-stop button will be connected to each train of PSS0.

### 2.3.4 Position monitoring switches

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 technologies.

#### - Mechanical safety switch with separate actuator

The mechanical safety switch has **Positive opening (→)** operation. The NC contacts of the switch are forced open mechanically, positively-driven and reliably by the plunger. (an internal mechanism forcibly separates normally closed contacts and prevents them from welding together - allowing the safety circuit to open. Requirements in IEC 60947-5-1, Annex K prevent the reliance on spring action alone to separate the contacts.)

The switch itself will be mounted on the fixed part with the actuator fitted on the door. The switch will have 2 sets of NC safety contacts, each connected to one train of PSS0.

Figure 9 shows the mechanical safety switch with separate actuator.



**Figure 9: Mechanical safety switch with separate actuator**

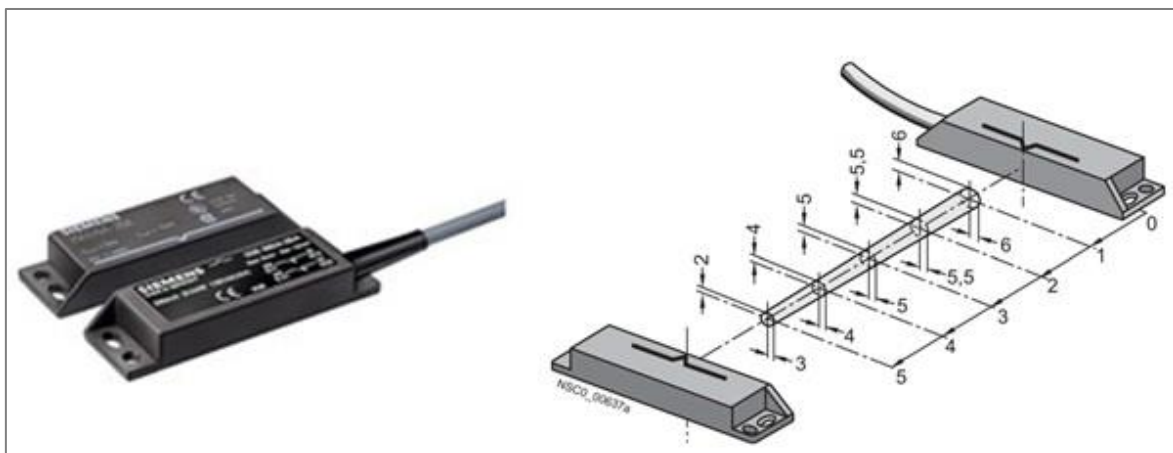
- Non-contact magnetically operated safety switch

A magnetically operated switch comprises a coded switching magnet and a contact block (sensor unit). The magnetic safety switch has the following features:

- Tamper-proof protective door monitoring
- Small footprint
- SIL 3 acc. to IEC 61508, achievable with single switch pair

The switch itself will be mounted on the fixed part with the actuator fitted on the door. The switch will have 2 sets of NC safety contacts (built-in Reed switches), each connected to one train of PSS0.

Figure 10 shows the magnetic safety switch, and its operation.



**Figure 10: Non-contact magnetically operated safety switch**

### 2.3.5 Door lock and key exchange system

- Access door lock

The access door to PSS0 controlled area will use a standard Fortress amGard *proLok*. It's a heavy duty, solenoid controlled (energize to unlock) switch interlock.

It will be unlocked only when the solenoid is energized by PSS0 PLC, and the Safety key is removed from slot 3.

The lock specification is as below:



## SHORT KEY ASSEMBLY FRONT FACING AUTO HEAD ASSEMBLY PUSH IR, WITH KEY RESET, 40MM SAFETY KEY ADAPTOR

### - Key exchange system

The PSS0 key exchange system (Trapped Key Interlock Switches) will be used to ensure that a predetermined sequence of events takes place in order to remove the electrical before personnel get access to PSS0 controlled area. This system ensures that the access process to PSS0 controlled areas is followed and cannot be circumvented or short cut. The unit will contain stainless steel mechanical lock modules with uniquely coded keys.

There are two keys in the PSS0 key exchange system Access Key and Safety Key.

The Access key will be installed inside an enclosure in G01-FEB-level 90 near the ISrc HV PS.

The sequence of actions to grant personnel safe access to PSS0 controlled are is shown in figure 11.

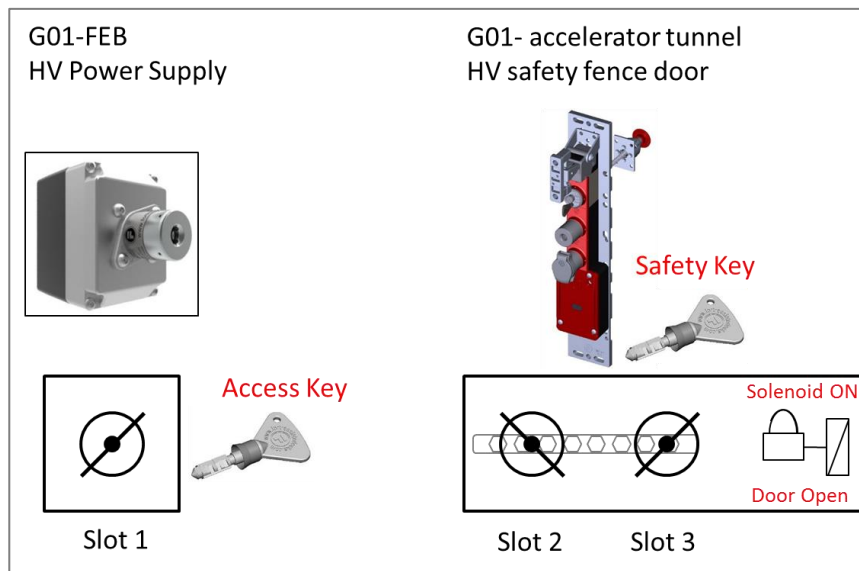


Figure 11: PSS0 key exchange system

### 2.3.6 Warning lights

Two warning lights will be installed on the outer side of the ISrc HV safety fence.

- Light for "HV ON" signalization.
- Light for "Beam ON" signalization.

The lights will be controlled by PSS0 PLC.

### **2.3.7 Contactor relays and contactors**

As described in [3], 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).
- Siemens contactor, AC-3 30 kW/400 V, DC 24V, 2 NO + 2 NC, 3-Pole, Size S3, Screw Connection (product number: 3RT1044-1BB44).

In order to use the Siemens Contactors for “Safety” applications, the contactors are provided with positively driven (mirror) contacts which meet or exceed the criteria for “Safety Contactors” according to IEC 60947-4 Annex F. When applying Safety Contactors in safety circuits, the NC auxiliary contacts must be wired in series or parallel and must be used as monitoring contacts with feedback to the safety evaluation device (i.e. safety relay or failsafe logic controller).

## **2.4 PSS0 cable containment and cable design**

### **2.4.1 PSS0 cable containment design**

As part of safety requirements specifications in accordance with IEC 61508:2010, the two independent PSS0 trains should be physically separated to reduce the possibility of the PSS0 being affected by the same external events. Therefore, in any two train personnel safety system, the cables of each train (from sensor to logic solver to actuator) will run through two separated, enclosed, sealed and marked containments/conduits, which are dedicated to PSS0.

The details of PSS0 cable containment design can be found in Accelerator FEB Electrical Cable List [4].

### **2.4.2 PSS0 cables**

Considering the requirements such as temperature, ionizing radiation, EMI and RFI at various levels in Accelerator, Target and Neutron instruments buildings, the signal cables to be used for ESS Personnel Safety Systems are radiation resistant (up to 1000 kGy), high temperature (up to 125 °C), of low frequency industrial cable type. The PSS signal cables will have an overall screen to mitigate the EMI effect. The PSS signal cables are RADOX 125 and are manufactured by HUBER+SUHNER. RADOX 125 has a life span of 20,000 hours at a conductor temperature of 120 °C, which is approx. 2.5 years. If it is used at another temperature (e.g. 80 °C), the cable lifetime will be 320,000 hours. The cable specification is shown in figure 12.

Thermal resistance	20 000 h/ 125 °C
Flame retardant	Yes
Halogen free	Yes
Smoke generation	Low
Resistance to ionizing radiation	1000 KGy

**Figure 12: PSS cable specifications**

## DOCUMENT REVISION HISTORY

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<b>Revision</b>	<b>Reason for and description of change</b>	<b>Author</b>	<b>Date</b>
1	First issue	Morteza Mansouri	2018-02-07
2			

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