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Interlock PLC user manual of the ESS ERIC Source

	Name	Affiliation
Owner	Jean-François Denis	CEA
Author	Tom Joannem	CEA
Reviewers	Françoise Gougnaud	CEA
Approvers	Florence Ardellier	CEA

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1. INTRODUCTION

1.1 Description

The goal of this document is to give as much data as possible to the ESS Source PLC interlock user for a good use of this system.

1.2 Acronyms

The following words, abbreviations and acronyms are used in this document:

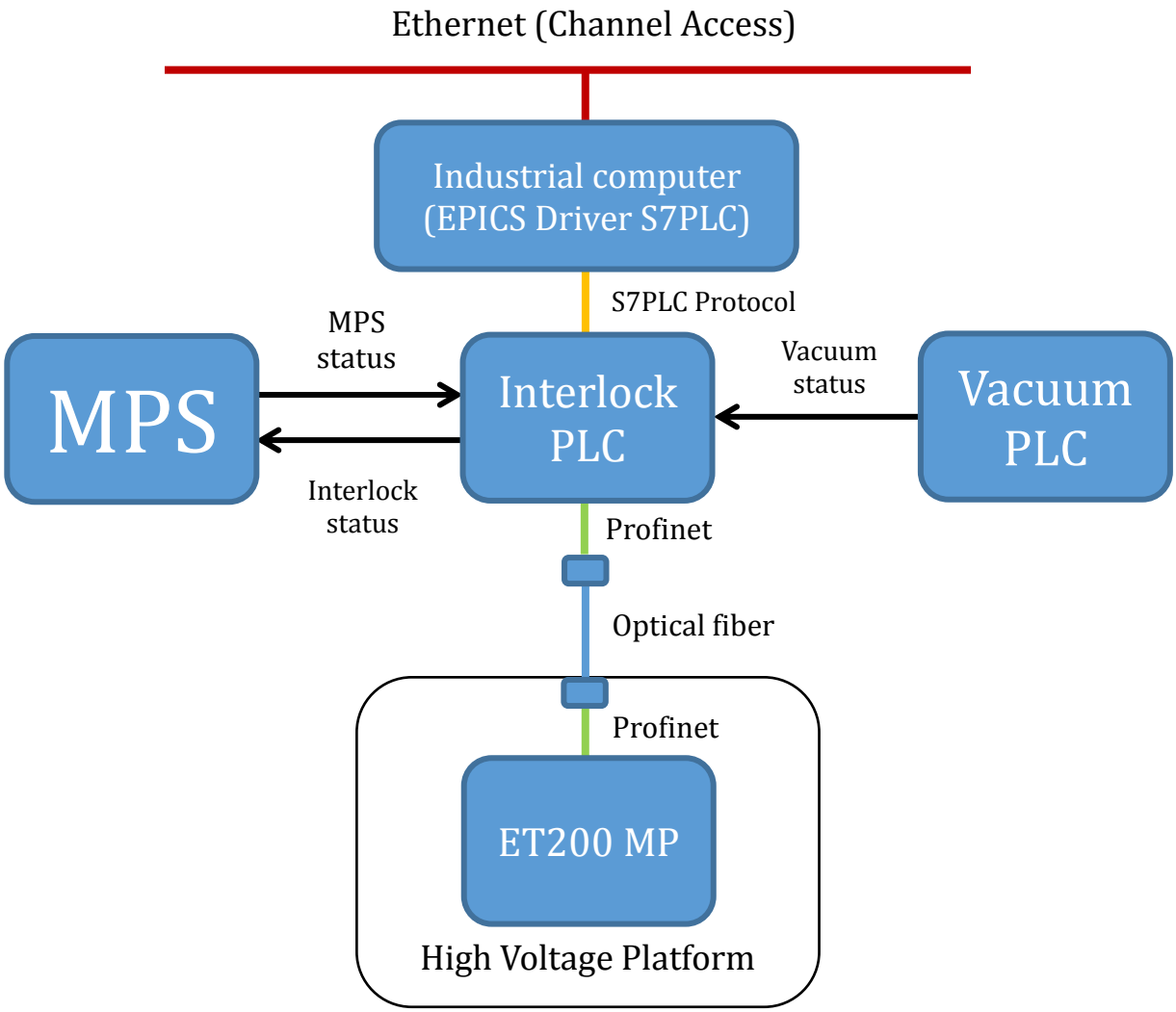
Abbreviation	Definition
ACCT	AC Current Transformer (diagnostic)
ATU	Automatic Tuning Unit
BOY	Best OPI Yet (Display editor)
CSS	Control System Studio
EPICS	Experimental Physics and Industrial Control System
ESD	Electro Static Discharge
ESS PS	ESS Proton source
GUI	Graphic User Interface
IOC	Input Output Controller
LEBT	Low Energy Beam transport
MPS	Machine Protection System
PLC	Programmable Logic Controller
RD	Reference Document

2. PLC CONTROL ARCHITECTURE

2.1 Architecture overview

ESS Source PLC architecture is composed of fieldbuses and protocols as Channel Access, S7PLC and Profinet, devices as Industrial computer, Interlock PLC, Vacuum PLC, MPS and ET200 MP and communication signals.

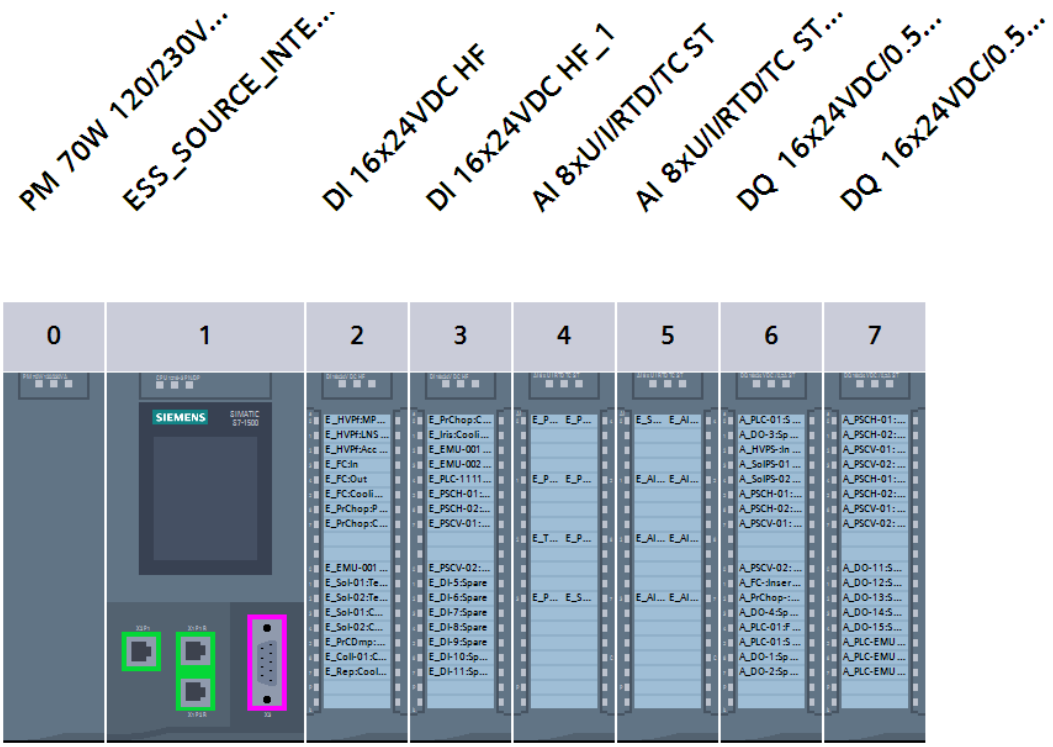
From top to bottom: an industrial computer gives the possibility to communicate with Channel Access to other EPICS devices and with S7PLC to the Interlock PLC.
This PLC communicate with Vacuum PLC for vacuum status, with MPS for MPS and interlock status with relays and dry contacts, and finally with ET200 MP for input/output on the High voltage platform. The optical fiber used for this communication gives a galvanic isolation.



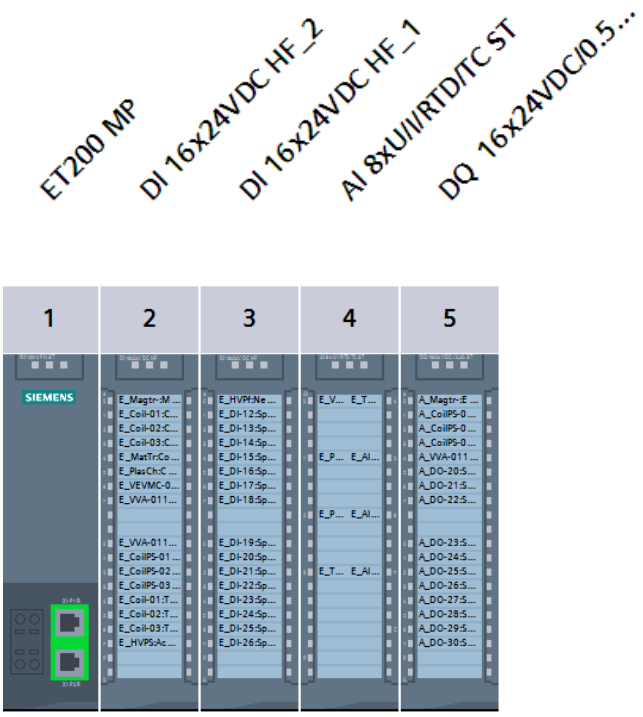
2.2 PLC configuration

Configuration of Ground PLC and High Voltage platform.

2.2.1 Ground PLC



2.2.2 ET200 MP



2.3 Communications

This part will give details about communications between the interlock PLC and other devices.

2.3.1 Machine Protection System (MPS)

The most important communication that must never be disabled is between the interlock PLC and the Machine Protection System.

The MPS have to know, permanently, the status of the interlock PLC. If the PLC detects a problem, the MPS must be able to shut down other systems. The PLC has also to know the status of the MPS. If a problem appears on the MPS or from other devices, the PLC must be able to shut down the local system.

In order to do that, a wired connection will be established between those two systems. Two twenty four volts signals will be implemented. One for the status of the PLC to the MPS, and a second signal for the status of the MPS to the PLC.

These two signals will be every time at the maximum value, twenty-four volts. This logic gives us the possibility to detect if the wire between the two systems is broken. If it is broken, the communication is disabled between PLC and MPS. The voltage is at zero volts and security systems have to stop.

2.3.2 Vacuum PLC

The communication between the Vacuum and the Interlock PLC will be wired connected. There be only one signal between these two PLC.

The signal will come from the Vacuum PLC to the Interlock PLC and will use the same logic than the MPS. A permanent twenty four voltage signal will be established between the two PLC. If a broken wire or a loss of communication appears, the Interlock PLC has to stop the local system.

2.3.3 EPICS

The interlock PLC has to communicate with EPICS. These exchanges of data will be able by the utilization of an Input Output Controller. This controller deal data by the Ethercat fieldbus between the interlock PLC and other EPICS devices.

The Input Output Controller will be installed on an Industrial Computer. This computer will communicate with the interlock PLC via the S7PLC protocol. It will also communicate with EPICS devices via the EtherCAT network.

2.3.4 Remote I/O system, ET200 MP

A part of the sensors and actuators of the Interlock PLC are located on the high voltage platform. An electric separation is needed between the CPU and these data because of the high voltage.

To make this separation, a distributed Input/output system is used. It allows us to communicate with sensors and actuators with the same cards as the Interlock PLC but, on the platform.

The ET200 MP is a Siemens device, like the PLC CPU, and can be configured with the same cards. The communication between these two devices is done with the Siemens industrial fieldbus, Profinet.

This fieldbus is used with an optical fiber between the ground and the high voltage platform. This architecture gives an electric separation, a fast and secured communication and a flexible configuration to the system.

3. INTERLOCK PROCEDURES

Every potential problem is classified in an event.

Each event is memorized and must be acknowledged by an operator.
After the detection of a fault, this one can't come back to the normal mode.
An operator has to acknowledge this default, by resetting it, with a dedicated button.
This operation done, the normal process can start again.

Some interlock procedures are disabled as long as LEBT devices are not installed. They are noticed with a RED color: sensor.

Events are defined as followed:

3.1 Event A: No HV lan

- If the lan (Profinet) connection with the HV platform is lost

  Then:

  - Source status to LNS Safety system : OFF
  - Magnetron enable command: OFF
  - Coil 1 power supply enable command : OFF
  - Coil 2 power supply enable command : OFF
  - Coil 3 power supply enable command : OFF
  - H2 isolation valve open command : CLOSE

3.2 Event B: Coils off

- If Coil 1 cooling water flow status is NOK
- Or if Coil 2 cooling water flow status is NOK
- Or if Coil 3 cooling water flow status is NOK
- Or if Coil 1 temperature status is NOK
- Or if Coil 2 temperature status is NOK
- Or if Coil 3 temperature status is NOK
- Or if HV cooling water temperature inlet temperature is NOK (25°C)

Then:

- Coil 1 power supply enable command : OFF
- Coil 2 power supply enable command : OFF
- Coil 3 power supply enable command : OFF

3.3 Event C: Magnetron off

- If Machine protection system is NOK
- Or if LNS safety system status is NOK
- Or if Chopper power system status is NOK
- Or if chopper chopping voltage alarm is NOK
- Or if solenoid 1 temperature status is NOK
- Or if solenoid 2 temperature status is NOK
- Or if solenoid 1 cooling water flow status is NOK
- Or if solenoid 2 cooling water flow status is NOK
- Or if beam stop cooling water flow status is NOK
- Or if collimator cooling water flow status is NOK
- Or if electrodes cooling water flow status is NOK
- Or if chopper cooling water flow status is NOK
- Or if IRIS cooling water flow status is NOK
- Or if Ground cooling water inlet temperature is NOK
- Or if horizontal steerer 1 current is NOK
- Or if horizontal steerer 2 current is NOK
- Or if vertical steerer 1 current is NOK
- Or if vertical steerer 2 current is NOK
- Or if solenoid 1 current is NOK
- Or if solenoid 2 current is NOK
- Or if coil 1 cooling water flow status is NOK
- Or if coil 2 cooling water flow status is NOK
- Or if coil 3 cooling water flow status is NOK
- Or if matching transformer cooling water flow status is NOK
- Or if plasma chamber cooling water flow status is NOK
- Or if vacuum status is NOK
- Or if coil 1 power supply status is NOK
- Or if coil 2 power supply status is NOK
- Or if coil 3 power supply status is NOK
- Or if coil 1 temperature status is NOK
- Or if coil 2 temperature status is NOK
- Or if coil 3 temperature status is NOK
- Or if HV cooling water inlet temperature is NOK

Then:

- Source status to LNS safety system : OFF
- Magnetron enable command : OFF

3.4 Event D: Chopper off

- If the vacuum status (ground) is NOK
- If the vacuum status (HV platform) is NOK

Then:

- Chopper high voltage enable command: OFF
- H2 isolation valve open command: CLOSE

3.5 Event E: Solenoid 1 off

- If the solenoid 1 temperature status is NOK
- Or if the solenoid 1 cooling water flow status is NOK
- Or if the ground cooling water inlet temperature is NOK

Then:

- Solenoid 1 power supply enable command: OFF
- Horizontal steerer 1 power supply enable command: OFF
- Vertical steerer 1 power supply enable command: OFF

3.6 Event F: Solenoid 2 off

- If the solenoid 2 temperature status is NOK
- Or if the solenoid 2 cooling water flow status is NOK
- Or if the ground cooling water inlet temperature is NOK

Then:

- Solenoid 2 power supply enable command: OFF
- Horizontal steerer 2 power supply enable command: OFF
- Vertical steerer 2 power supply enable command: OFF

3.7 Event G: HV off

- If the access status (ground) is NOK
- Or if the vacuum status is NOK
- Or if the access status (HV platform) is NOK
- Or if the neutral to ground resistor switch status is NOK
- Or if vacuum level is NOK

Then:

- High voltage power supply interlock command: OFF

3.8 Event H: No ground lan

- If the ground to HMI connection is lost

Then:

- High voltage power supply interlock command: OFF
- Solenoid 1 power supply enable command: OFF
- Solenoid 2 power supply enable command: OFF
- Horizontal Steerer 1 power supply enable command: OFF
- Horizontal Steerer 2 power supply enable command: OFF
- Vertical steerer 1 power supply enable command: OFF
- Vertical steerer 2 power supply enable command: OFF
- Chopper high voltage enable command: OFF

3.9 Event I: Chopper off 2

- If the chopper power system status is NOK,
- Or if the chopper chopping voltage alarm is NOK

Then:

- After 5 ms, chopper high voltage enable command : OFF

3.10 Event J: Faraday cup off

- If water is NOK,
- Or if temperatures is NOK
- Or if vacuum is NOK

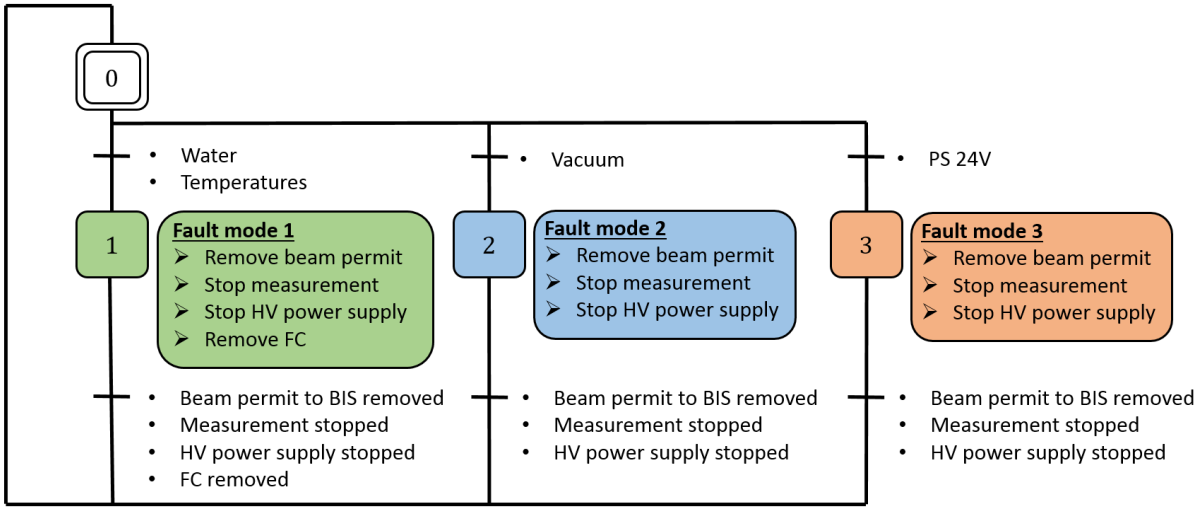
Then:

- Magnetron enable command : OFF
- High voltage power supply interlock command: OFF
- Measurement : OFF
- Faraday cup : Go to garage position

3.10.1 Faraday cup local interlock

A local interlock is needed to protect the FC of unwanted operation of this device. In particular the local protection system shall prevent the insertion of the FC if one of the EMU head is already inserted.

A similar logic as the one used for the EMU has to be implemented for the local protection of the FC, in particular in case of vacuum and/or water cooling fault. Some fault modes have been identified as well as the action for the interlock system; they are summarized in fig 2.



4. GRAPHIC USER INTERFACE

4.1 Interface architecture

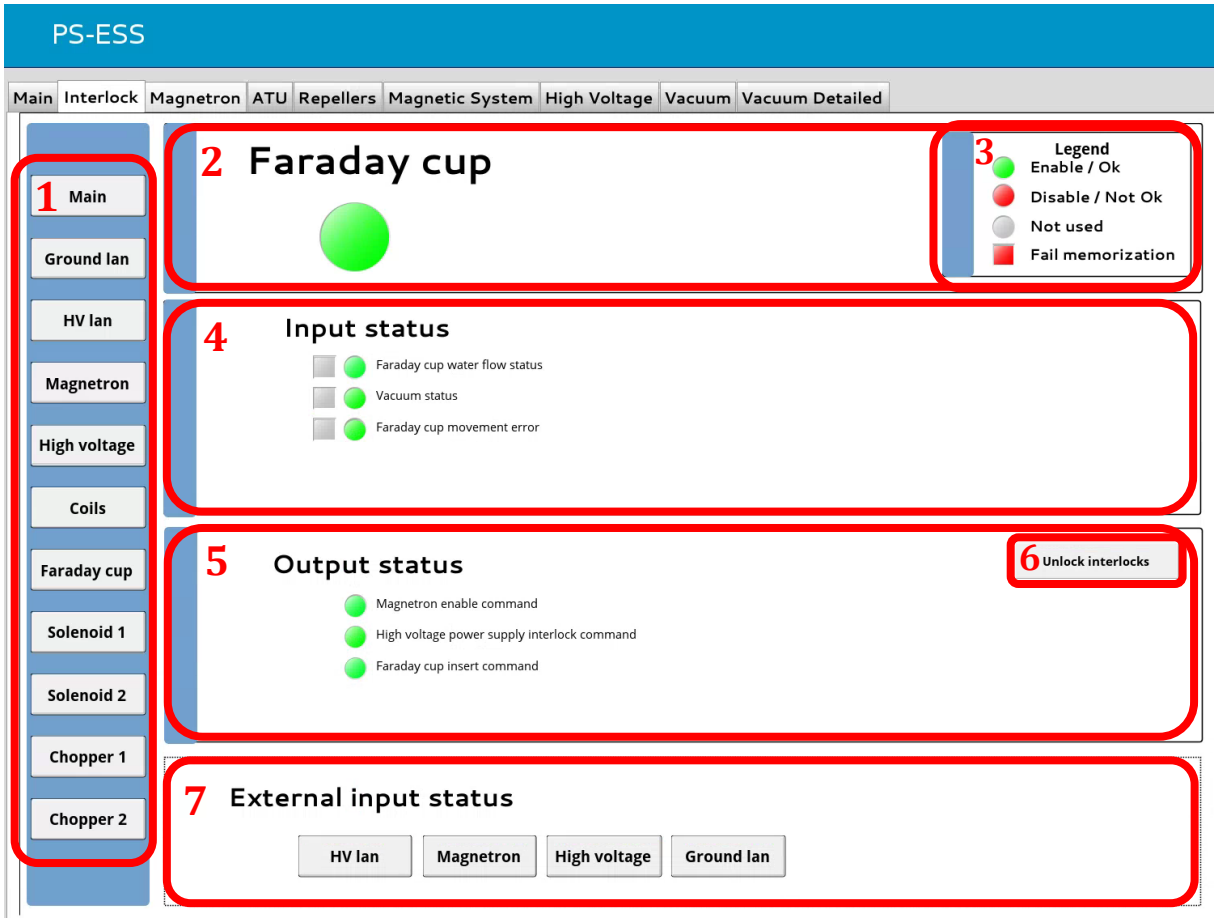
ESS Source PLC interlock views are composed as a classic structure, main view that give the possibility to go to sub-view, and each view is following the same vertical logic.

At the top of this structure, the main view, which have a LED at the top called "Global status of the Source interlock PLC". When everything is ok, this LED is GREEN. If at least one problem appear in one of events listed under this led, the main LED is going to be RED.

If the main LED is RED, one of the fail event at the center of the page should also be RED. In order to have details about the fail, you have only to go on the bouton called "Details" for the fail event and press on it.

4.2 View architecture

For each Event view, a vertical logic is applied, in order to make the interface ergonomic and easy to use, with only a vertical movement of the eye, example with the Faraday Cup view.



1 – Vertical view selection tool bar: This part of the view gives you the possibility to switch as much as you want from view to view. If a problem occurs on one Event view, the concerned button will be red to make easier and faster the navigation to the fail Event.

2 – Status of the event: You will find in this area the name of the Event and also the status of this one. If a problem was memorized there, and until it will be unlocked, the LED will be RED. When the problem will be solved and unlocked, this LED will be GREEN. If the Event is disabled, the LED is GREY.

3 – Legend: On each view, have been placed a legend, in order to help you if necessary.

4 – Input Status: Potential problems could occurred with different kind of inputs. Those inputs are located in this area. If at least one of those data are RED, the Event will be in fail mode and the top LED will also be RED.

Two kind of information are available for each input: Actual and memorized. As explain in the legend, the actual status is show with the circle LED and memorized with the rectangle LED.

The memorized LED is used in order to see if a data was wrong (RED) in the past.

Memorized could be RED and actual GREEN if a problem occurred on this data and that the sensor goes to the good position after that. If memorized is RED, specified fault mode is activated. In order to erased memorization LED, you have to click on Unlock interlocks when all actual LED of the event are green.

5 – Output Status: When an input sensor is, or was wrong, the fail mode is activated and specified output is shut down. When a LED in this area is RED, output specified is OFF and device is locked by the PLC. In order to release this output and make it active, Input Status have to be green and Unlock interlock button clicked.

Please remember that one output can be set or reset in many fault mode.

If you push Unlock interlocks button that the top LED is GREEN but that the output is still RED, you have to check with External input status, which must be also red, in order to see which fail mode you have to unlock before unlocking the actual event.

6 – Unlock interlocks button: This button gives you the possibility, when each Input actual status are GREEN, to release the fault mode and to set ON Output Status signals.

7 – External input status: as said before, one output could bet set or reset from more than one event. In this case, button located in this area give the possibility to follow the signal from view to view in order to check in the good order events to check to unlock specified output.

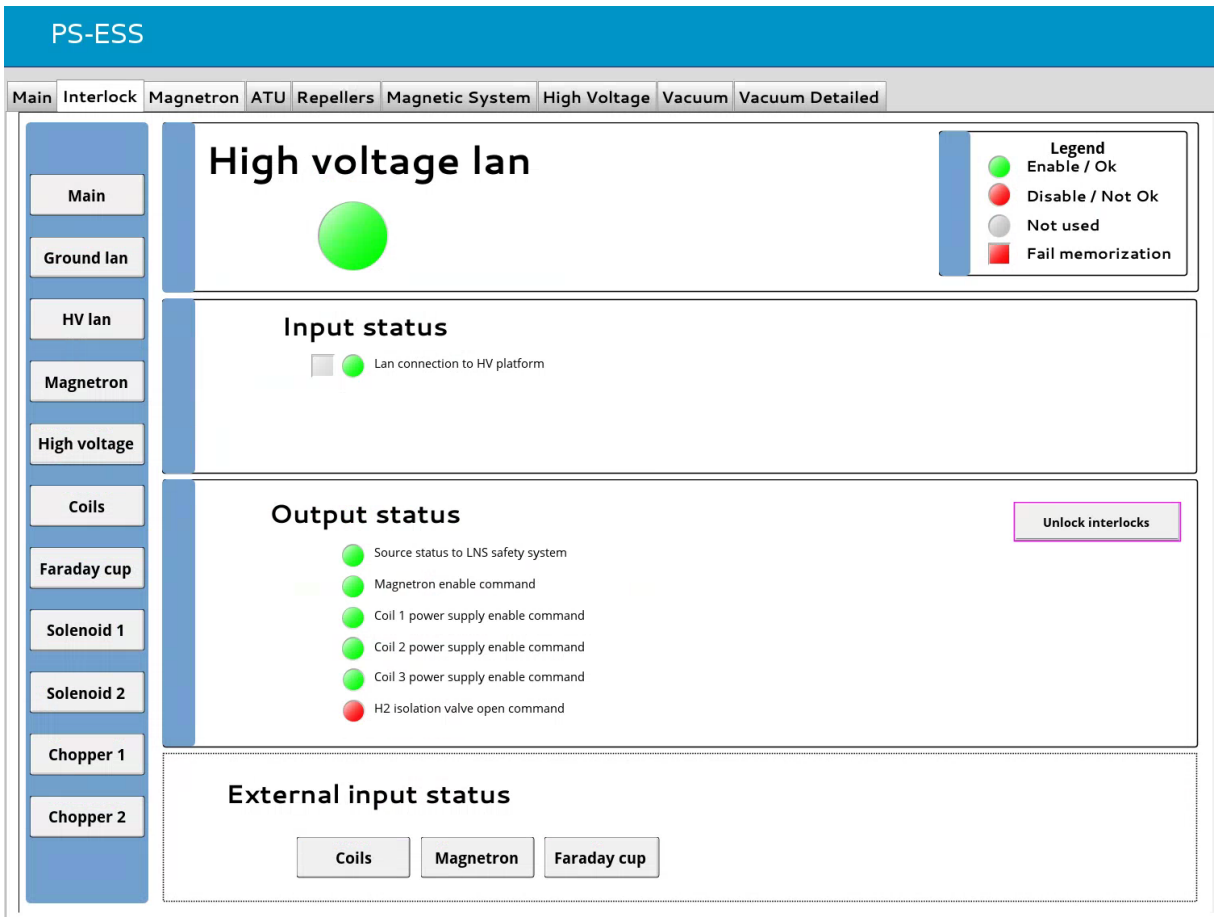
4.3 Detailed views

4.3.1 Main view

As specified in paragraph 4.1, this view give the status of the Source PLC, and each possible fail event. Each view and each event are detailed in following paragraphs.

Please note that GREY events are disabled because of missing LEBT devices.

4.3.2 View of Event A: No HV lan



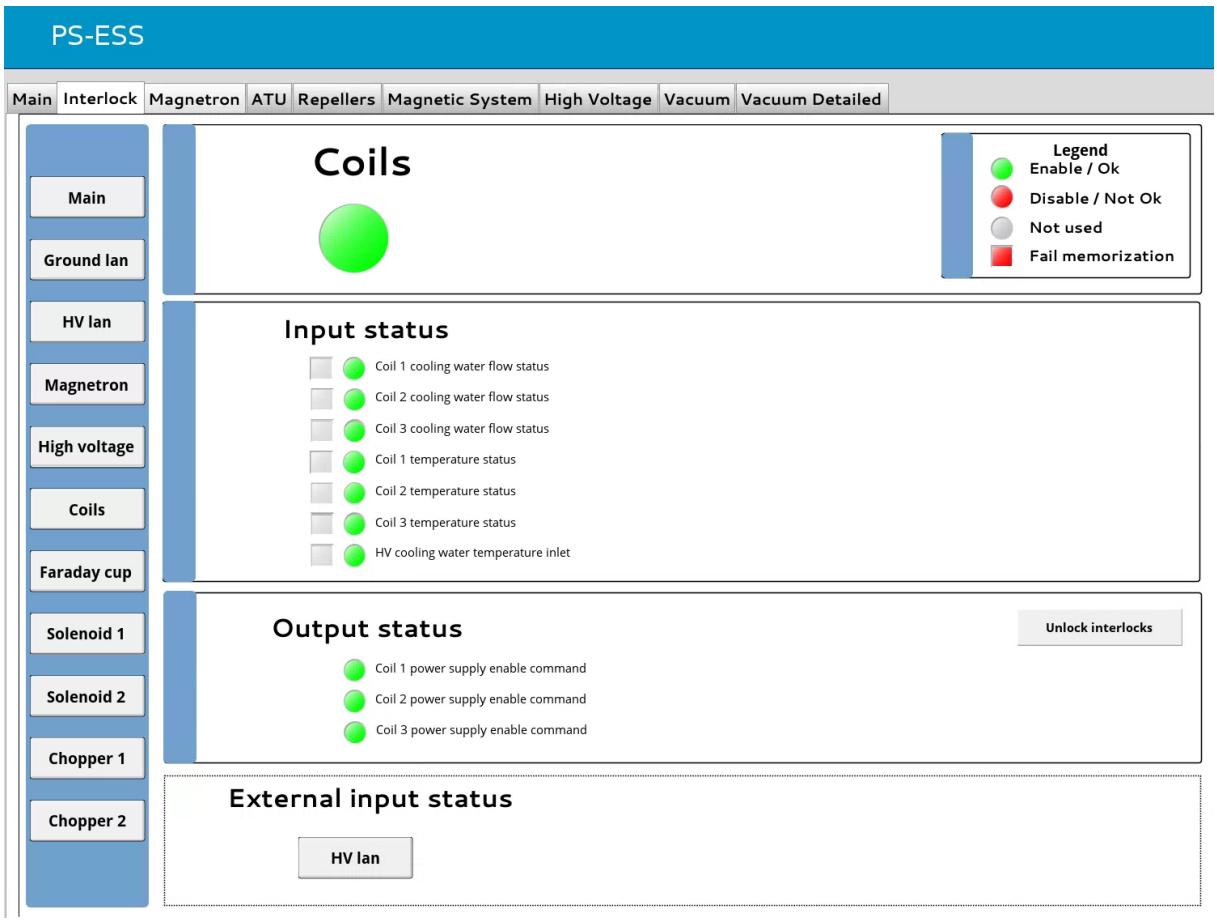
This view is following the same conditions are detailed in paragraph 3.1:

- If the lan (Profinet) connection with the HV platform is lost

  Then:

  - Source status to LNS Safety system : OFF
  - Magnetron enable command: OFF
  - Coil 1 power supply enable command : OFF
  - Coil 2 power supply enable command : OFF
  - Coil 3 power supply enable command : OFF
  - H2 isolation valve open command : CLOSE

4.3.3 View of Event B: Coils off



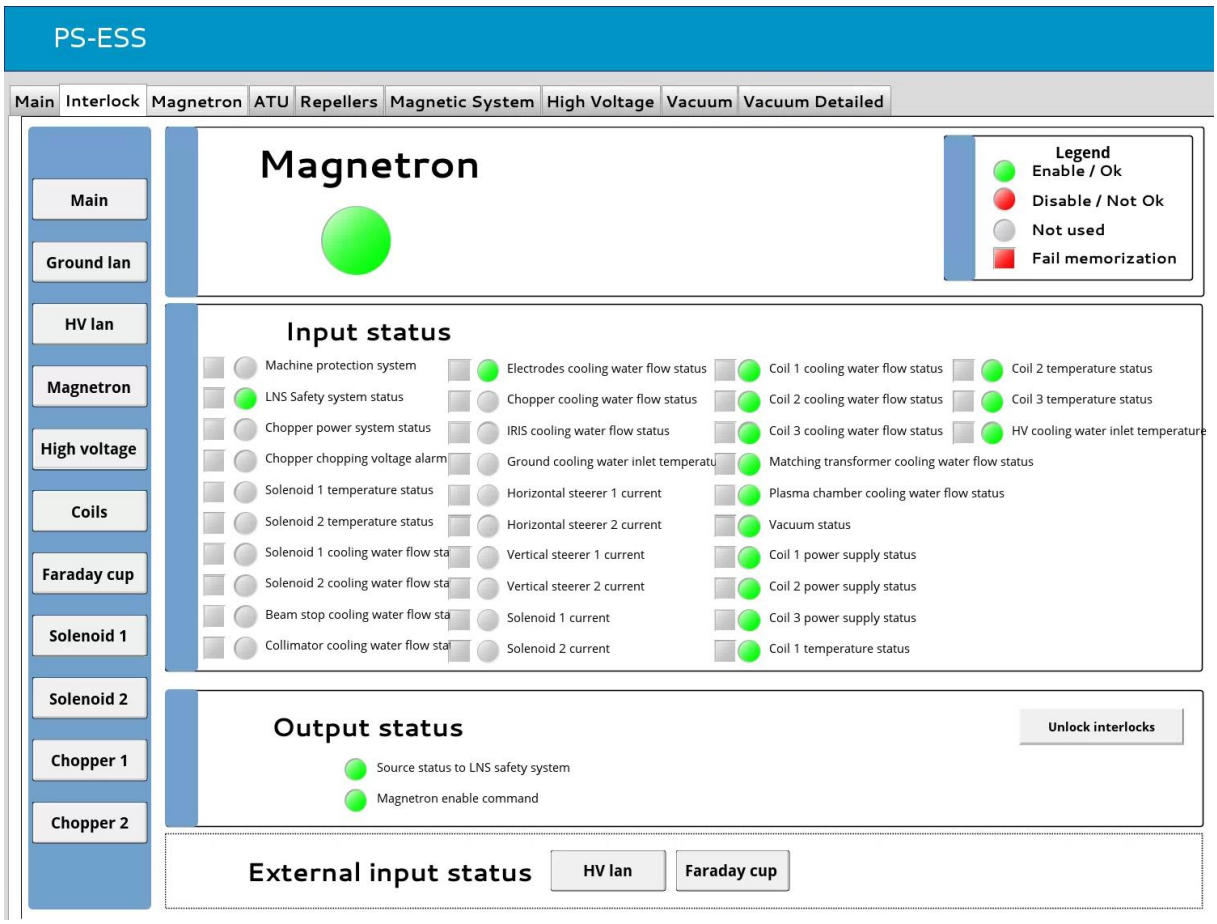
This view is following the same conditions are detailed in paragraph 3.2:

- If Coil 1 cooling water flow status is NOK
- Or if Coil 2 cooling water flow status is NOK
- Or if Coil 3 cooling water flow status is NOK
- Or if Coil 1 temperature status is NOK
- Or if Coil 2 temperature status is NOK
- Or if Coil 3 temperature status is NOK
- Or if HV cooling water temperature inlet temperature is NOK (25°C)

Then:

- Coil 1 power supply enable command : OFF
- Coil 2 power supply enable command : OFF
- Coil 3 power supply enable command : OFF

4.3.4 View of Event C: Magnetron



This view is following the same conditions are detailed in paragraph 3.3:

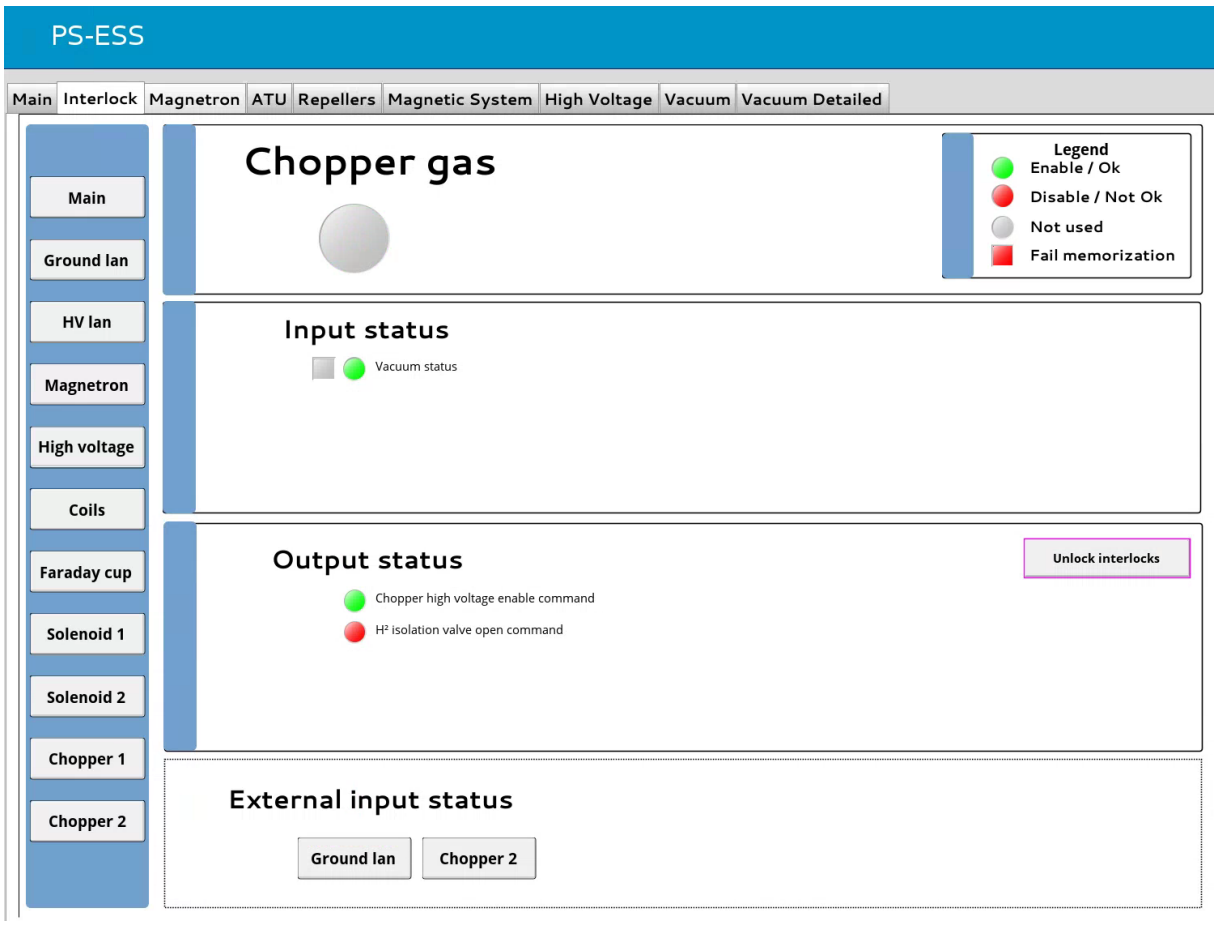
- If Machine protection system is NOK
- Or if LNS safety system status is NOK
- Or if Chopper power system status is NOK
- Or if chopper chopping voltage alarm is NOK
- Or if solenoid 1 temperature status is NOK
- Or if solenoid 2 temperature status is NOK
- Or if solenoid 1 cooling water flow status is NOK
- Or if solenoid 2 cooling water flow status is NOK
- Or if beam stop cooling water flow status is NOK
- Or if collimator cooling water flow status is NOK
- Or if electrodes cooling water flow status is NOK
- Or if chopper cooling water flow status is NOK
- Or if IRIS cooling water flow status is NOK
- Or if Ground cooling water inlet temperature is NOK
- Or if horizontal steerer 1 current is NOK
- Or if horizontal steerer 2 current is NOK
- Or if vertical steerer 1 current is NOK
- Or if vertical steerer 2 current is NOK
- Or if solenoid 1 current is NOK

- Or if solenoid 2 current is NOK
- Or if coil 1 cooling water flow status is NOK
- Or if coil 2 cooling water flow status is NOK
- Or if coil 3 cooling water flow status is NOK
- Or if matching transformer cooling water flow status is NOK
- Or if plasma chamber cooling water flow status is NOK
- Or if vacuum status is NOK
- Or if coil 1 power supply status is NOK
- Or if coil 2 power supply status is NOK
- Or if coil 3 power supply status is NOK
- Or if coil 1 temperature status is NOK
- Or if coil 2 temperature status is NOK
- Or if coil 3 temperature status is NOK
- Or if HV cooling water inlet temperature is NOK

Then:

- Source status to LNS safety system : OFF
- Magnetron enable command : OFF

4.3.5 View of Event D: Chopper off



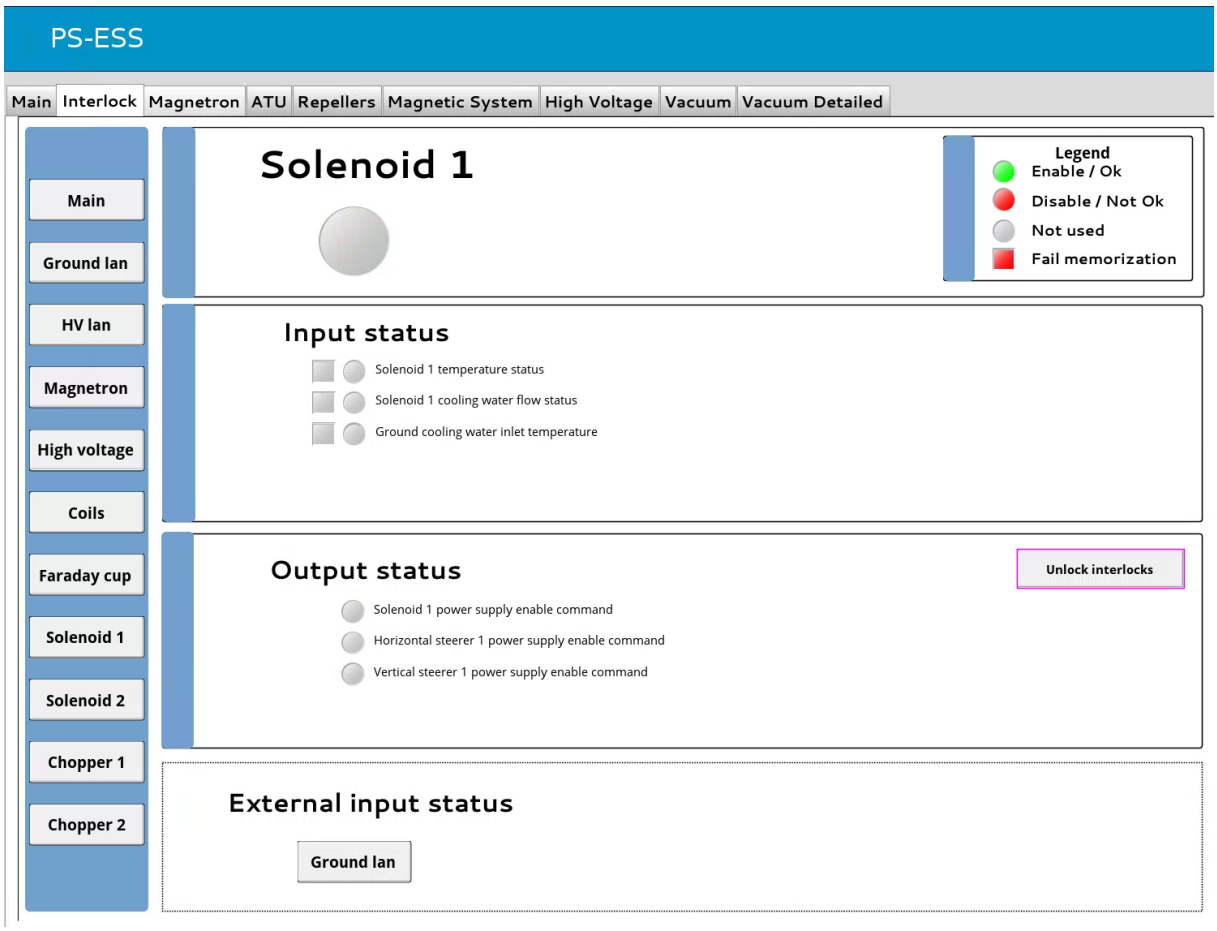
This view is following the same conditions are detailed in paragraph 3.4:

- If the vacuum status (ground) is NOK
- If the vacuum status (HV platform) is NOK

Then:

- Chopper high voltage enable command: OFF
- H2 isolation valve open command: CLOSE

4.3.6 View of Event E: Solenoid 1 off



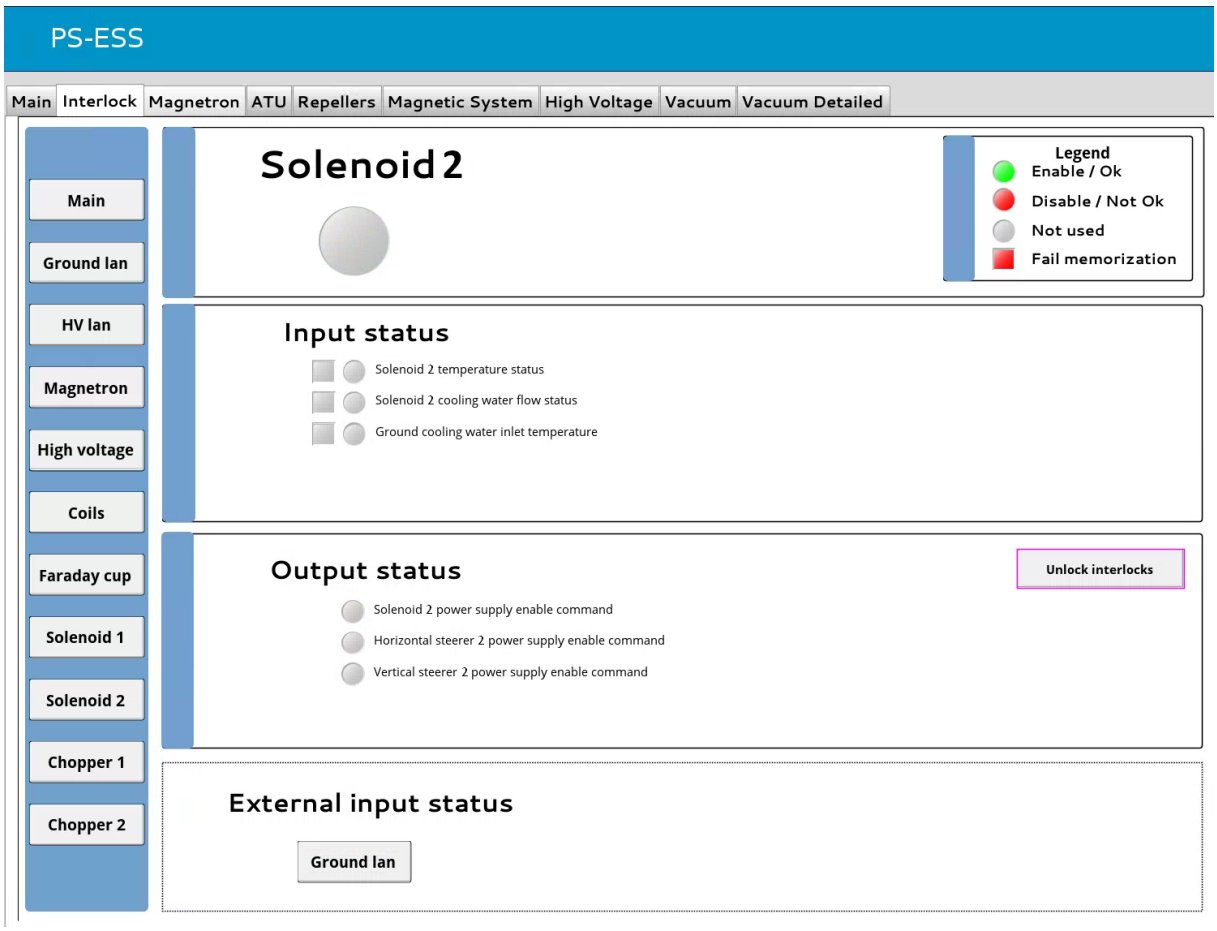
This view is following the same conditions are detailed in paragraph 3.5:

- If the solenoid 1 temperature status is NOK
- Or if the solenoid 1 cooling water flow status is NOK
- Or if the ground cooling water inlet temperature is NOK

Then:

- Solenoid 1 power supply enable command: OFF
- Horizontal steerer 1 power supply enable command: OFF
- Vertical steerer 1 power supply enable command: OFF

4.3.7 View of Event F: Solenoid 2 off



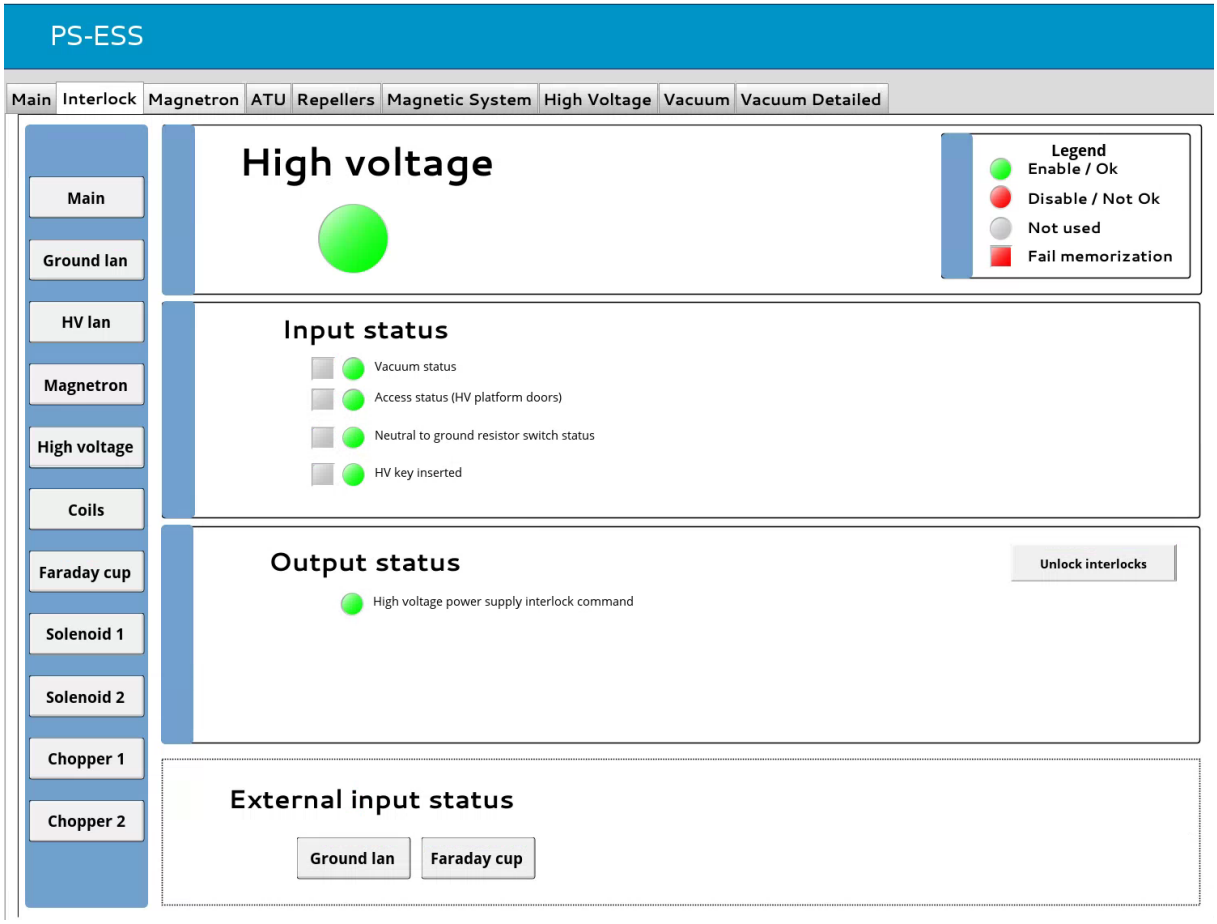
This view is following the same conditions are detailed in paragraph 3.6:

- If the solenoid 2 temperature status is NOK
- Or if the solenoid 2 cooling water flow status is NOK
- Or if the ground cooling water inlet temperature is NOK

Then:

- Solenoid 2 power supply enable command: OFF
- Horizontal steerer 2 power supply enable command: OFF
- Vertical steerer 2 power supply enable command: OFF

4.3.8 View of Event G: HV off



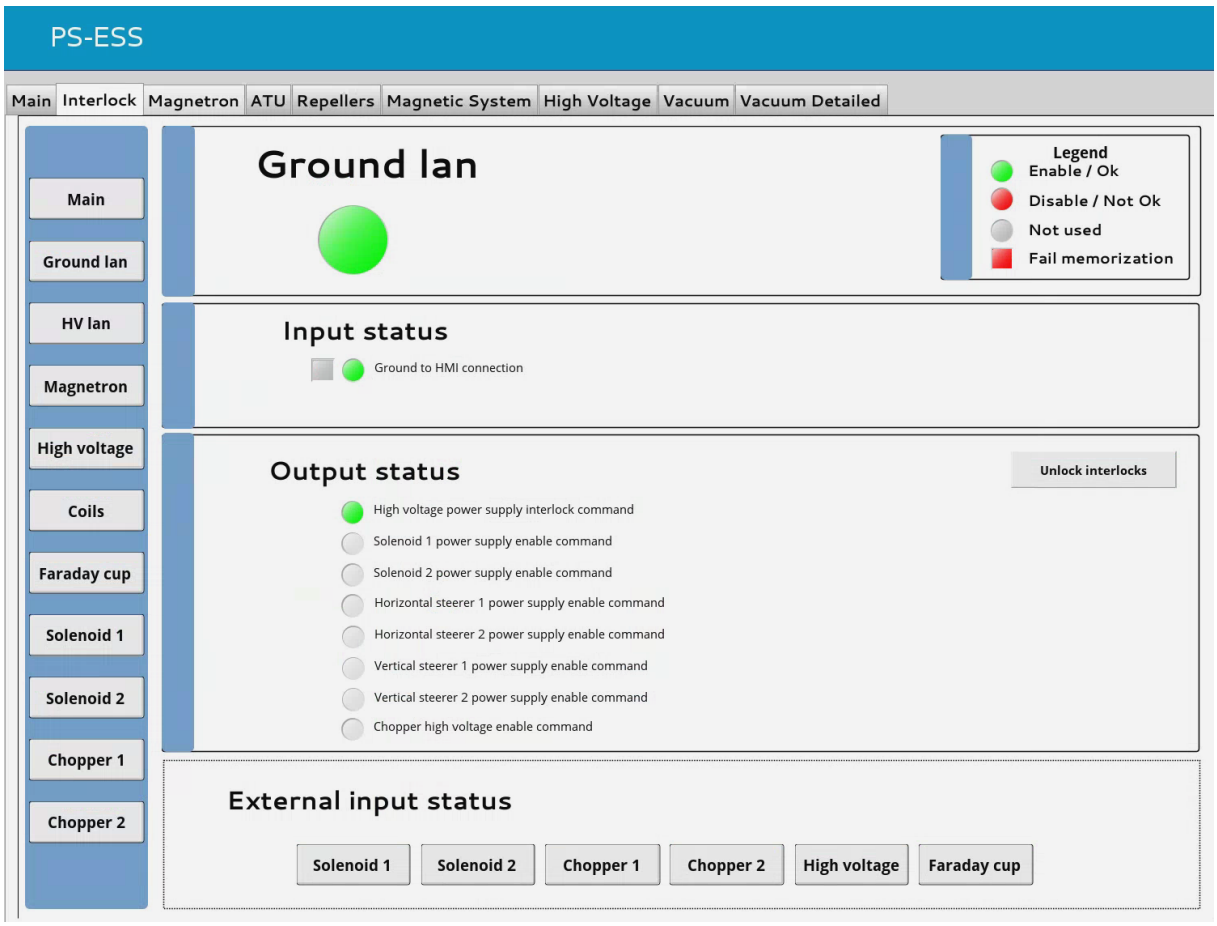
This view is following the same conditions are detailed in paragraph 3.7:

- If the access status (ground) is NOK
- Or if the vacuum status is NOK
- Or if the access status (HV platform) is NOK
- Or if the neutral to ground resistor switch status is NOK
- Or if vacuum level is NOK

Then:

➢ High voltage power supply interlock command: OFF

4.3.9 View of Event H: No ground lan



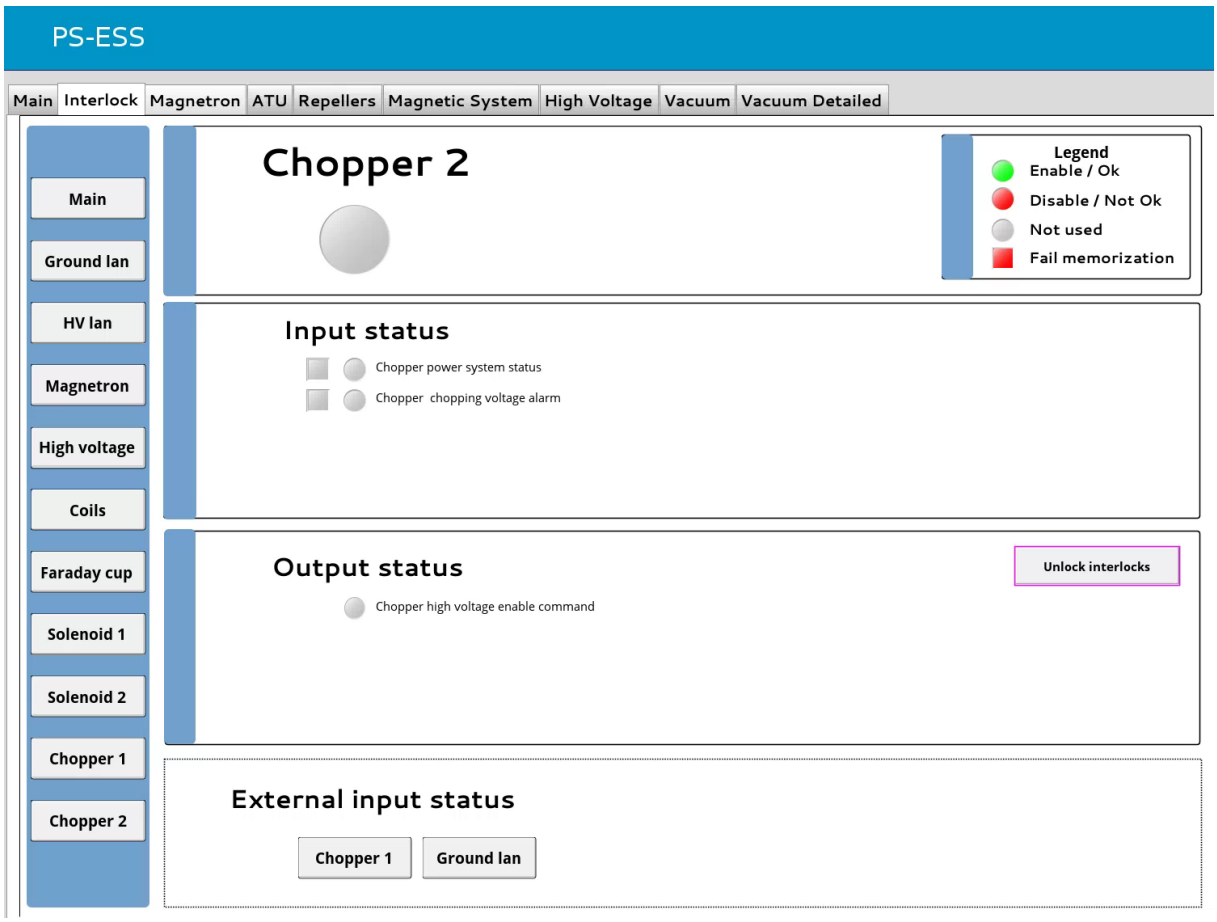
This view is following the same conditions are detailed in paragraph 3.8:

- If the ground to HMI connection is lost

  Then:

  - High voltage power supply interlock command: OFF
  - Solenoid 1 power supply enable command: OFF
  - Solenoid 2 power supply enable command: OFF
  - Horizontal Steerer 1 power supply enable command: OFF
  - Horizontal Steerer 2 power supply enable command: OFF
  - Vertical steerer 1 power supply enable command: OFF
  - Vertical steerer 2 power supply enable command: OFF
  - Chopper high voltage enable command: OFF

4.3.10 View of Event I: Chopper off 2



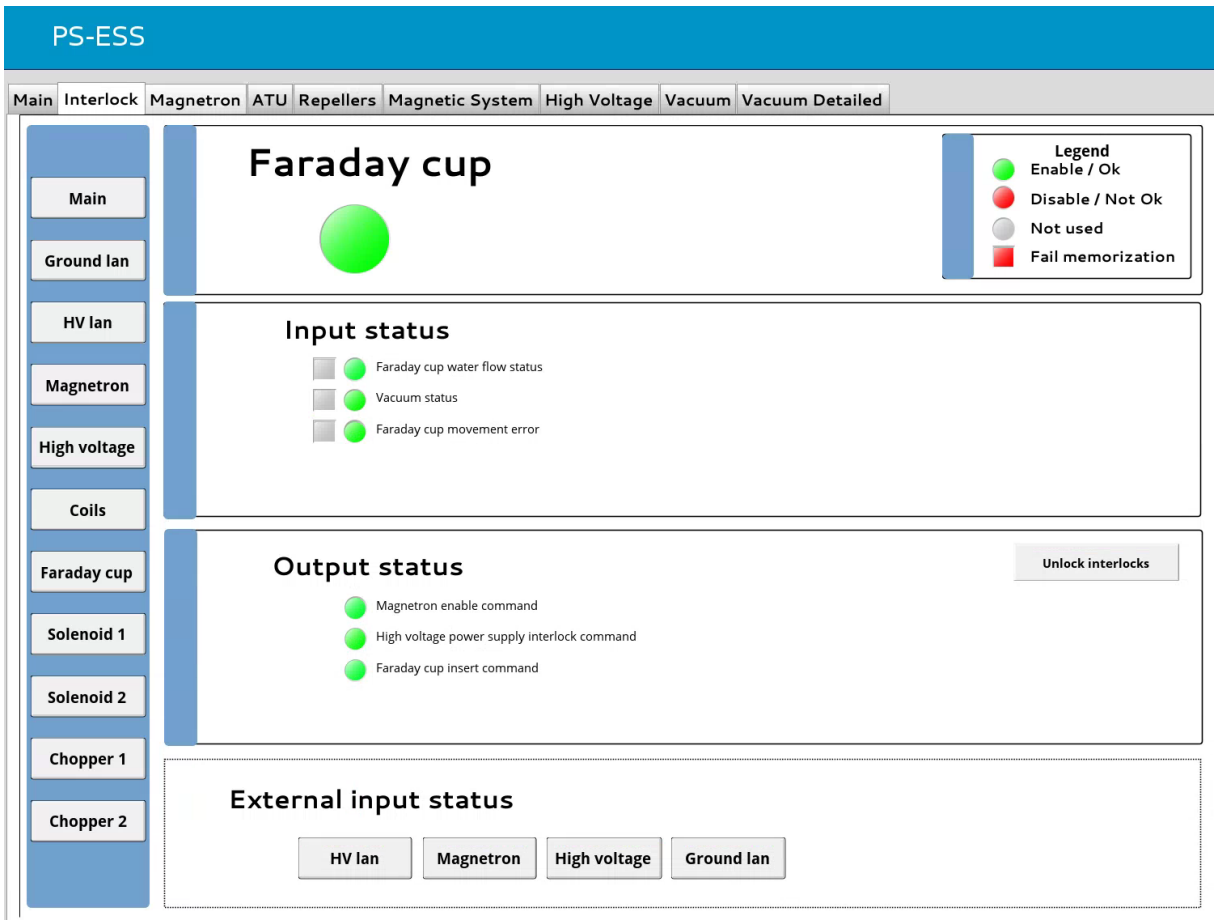
This view is following the same conditions are detailed in paragraph 3.9:

- If the chopper power system status is NOK,
- Or if the chopper chopping voltage alarm is NOK

Then:

- After 5 ms,
- Chopper high voltage enable command : OFF

4.3.11 View of Event J: Faraday Cup off



This view is following the same conditions are detailed in paragraph 3.10:

- If water is NOK,
- Or if temperatures is NOK
- Or if vacuum is NOK

Then:

- Magnetron enable command : OFF
- High voltage power supply interlock command: OFF
- Measurement : OFF
- Faraday cup : Go to garage position