The SPIDER Pulse Plant Configuration Environment

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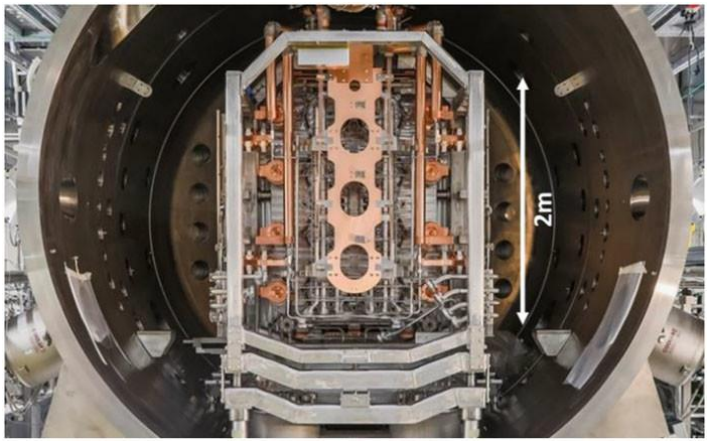
The SPIDER Experiment

- The Source for the Production of Ions of Deuterium Extracted from a Radio frequency plasma (**SPIDER**) experiment is a prototype devoted to the heating and diagnostic neutral beam studies in operation at the ITER Neutral Beam Test Facility (NBTF) at Consorzio RFX, Padova.
- SPIDER is the full-size ITER ion source prototype and the largest negative ion source in operation in the world.
- In view of ITER heating requirements to realize plasma burning conditions and instabilities control, SPIDER aims at
  - achieving long-time operation (3600 s) with beam energy up to 100 keV,
  - high extracted current density (above 355 $A.m^{-2}$ for H^- and above 285 $A.m^{-2}$ for D^-) at maximum beam source pressure of 0.3 Pa.
  - maximum deviation from uniformity must be kept under 10%.[1][2]



The inside of the SPIDER ion source.

NBTF High Voltage Hall with
- the insulating transformer (left)
- and the high voltage deck (right)

[1] V. Toigo *et al* 2019 *Nucl. Fusion* **59** 086058
[2] V. Toigo *et al* 2021 Fus. Eng. & Design **168** 112622

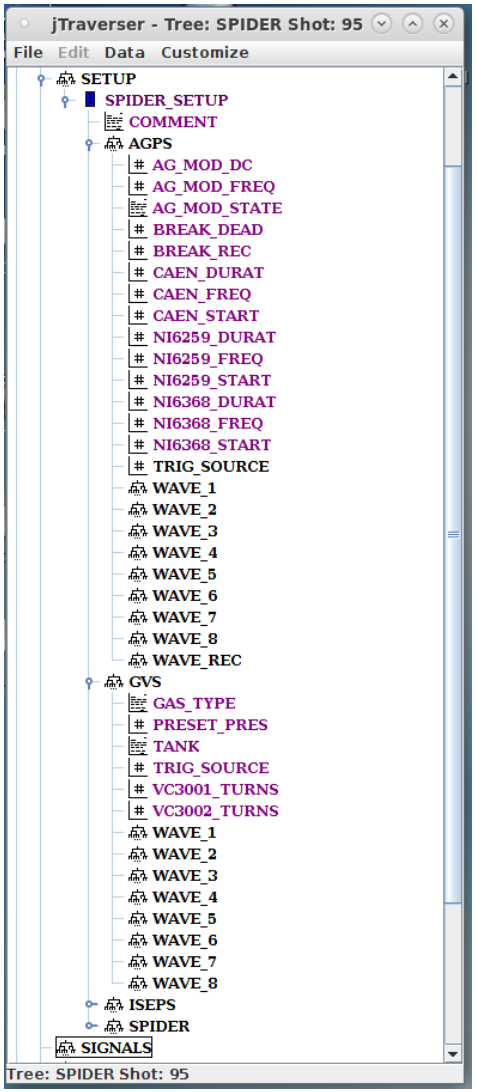
SPIDER Pulse Preparation – Past Situation

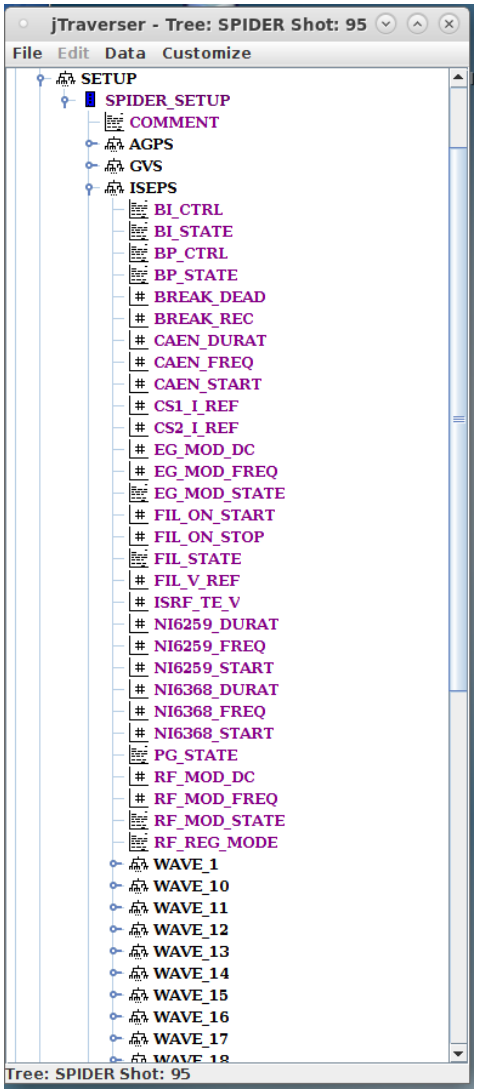
- SPIDER parameters were configured using an MDSplus Human Machine Interface (HMI) using specific pulse number to temporarily store the setup configuration;
- Using a command line the Session Leader (SL – Scientific Coordinator) could load previous setup from an executed shot or reference shot;
- SL could check all the configuration using MDSplus jScope, with all the waveforms;
- An external tool could create the long pulse setup in IDL and store it in a reference shot;

However

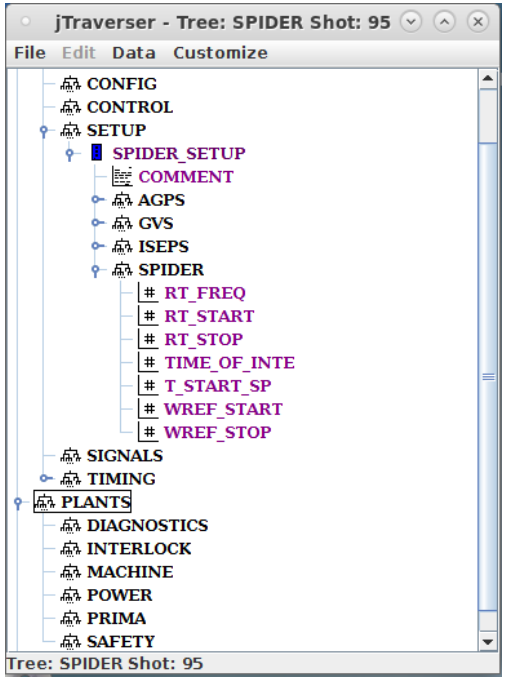
- Responsible Technician (RT – Engineer in Charge) had limited verification/comparison tools (jScope);
- No digital tool for configuration approval and communication process;
- Approval process had to be made on a signed paper;
- Only limited consistency check of parameters is made when loading config;
- This was a time consuming and error prone operation without automatic verification, approval sequence or feedback to the SL.
- It was designed and developed a solution using ITER Interface Operator Tools and NBTF tools with the experience from operating RFX experiment.

MDSplus SPIDER MDStree & Data Structure

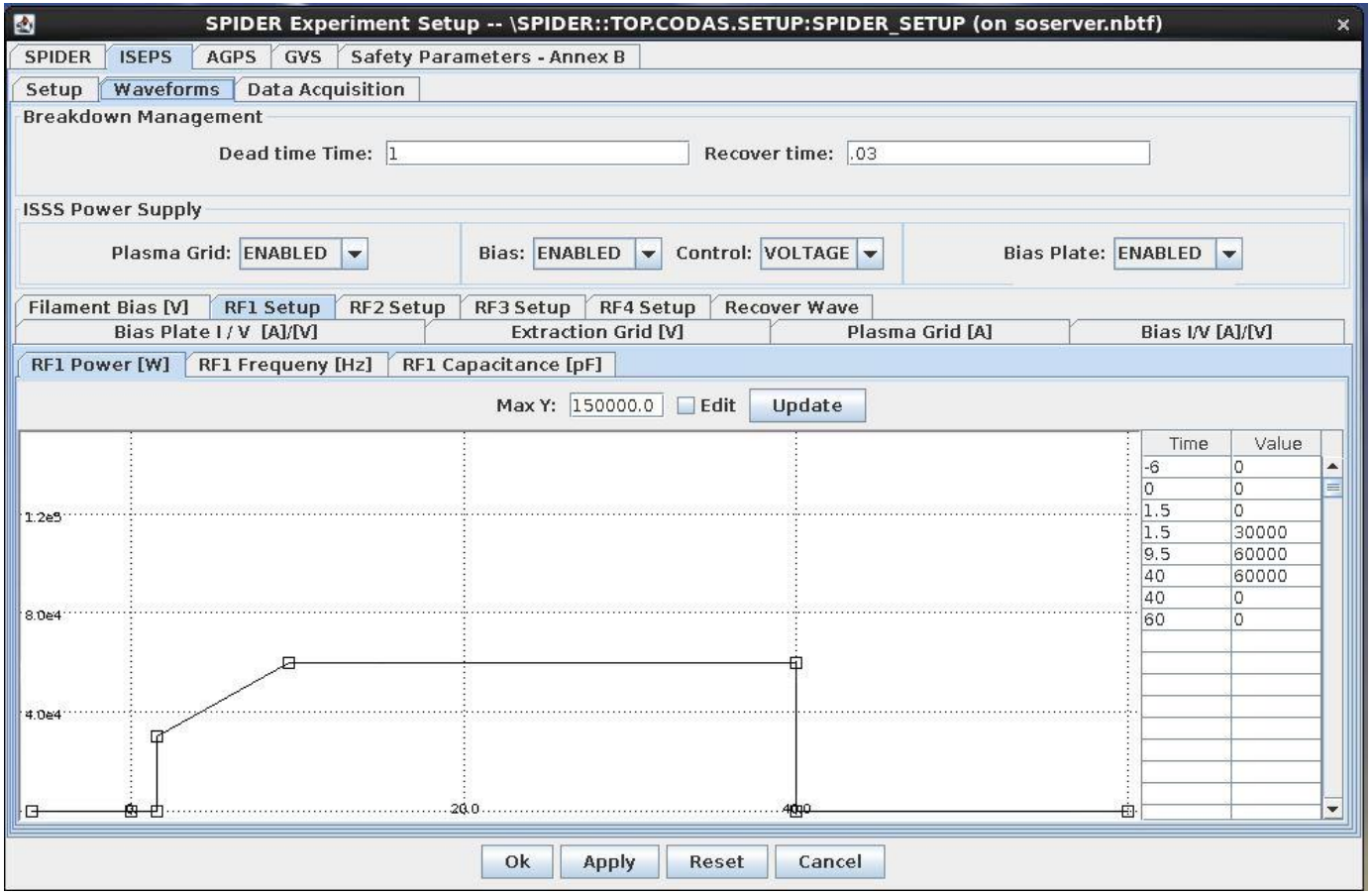




- All parameters are stored in the MDSplus SPIDER database
- Parameters can be accessed using the standard MDSplus libraries and tools

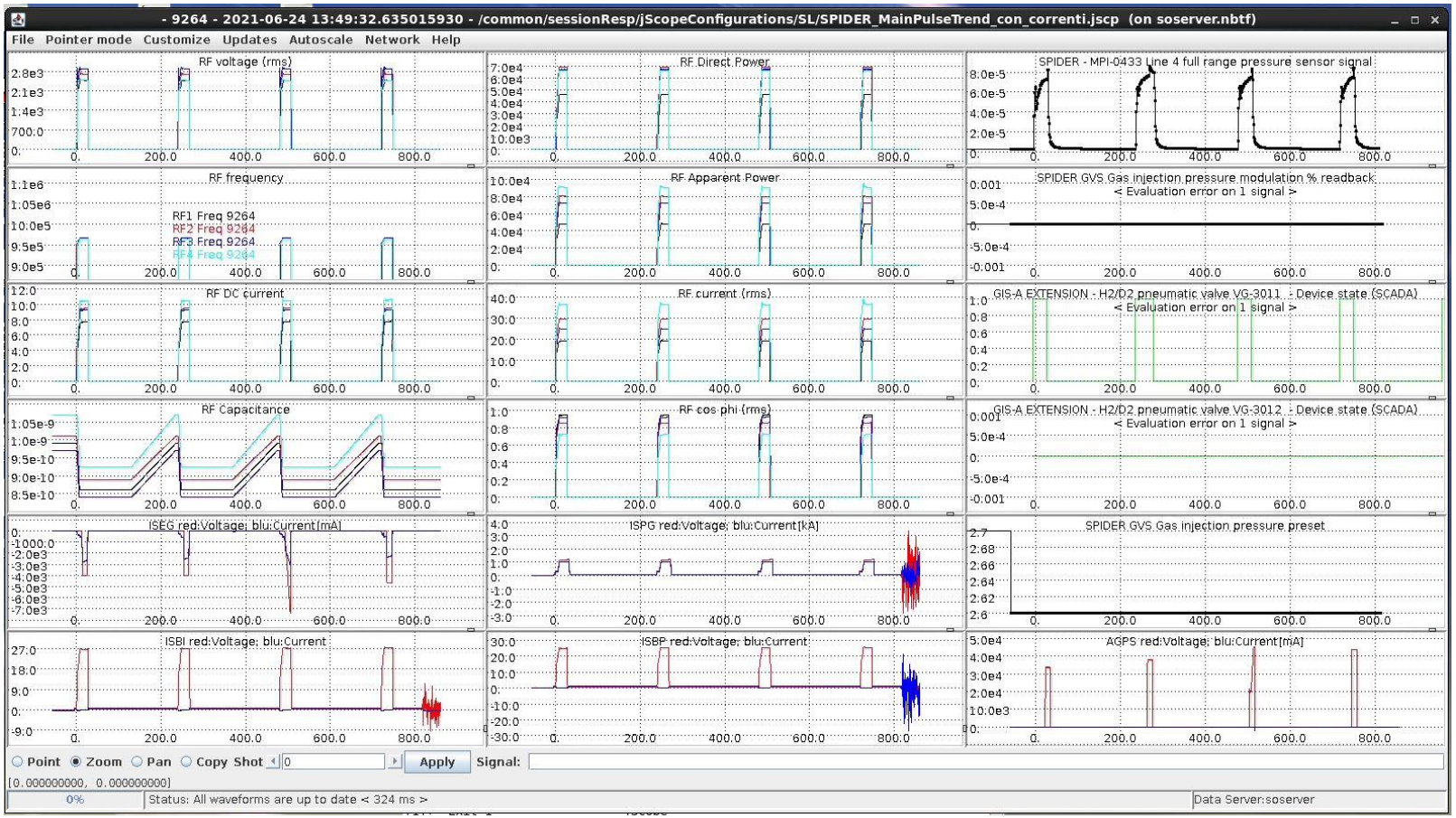


MDSplus Device Setup – SPIDER SL Configuration Tool

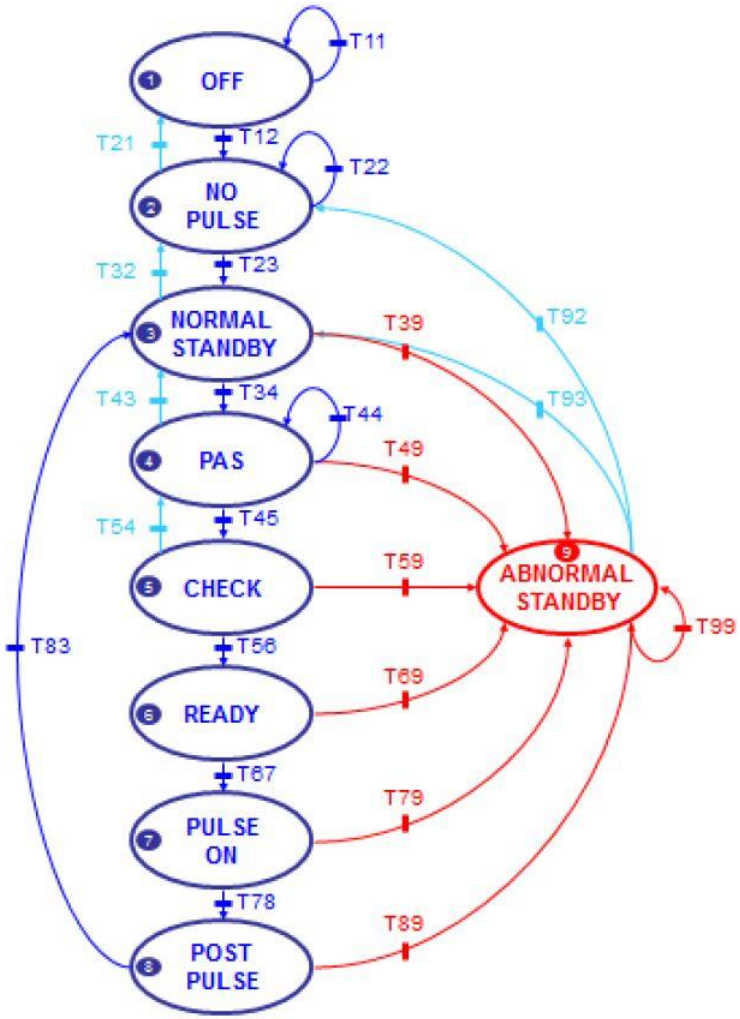


- All parameters can be set by SL using the MDSplus Device Setup tool
- The control and feed forward waveforms can be checked and changed using this tool, in case of simple waveforms
- A separate IDL tool can generate longer, repetitive and more complex waveforms

MDSplus jScope



SPIDER Pulse Sequence



- Configuration Tool shall be integrated into the SPIDER pulse sequence
- Pulse definition and approval shall be executed during NORMAL STANDBY state
- Multiple Sequence Pulses:
  - Submission to Operator Technician during NORMAL STANBY state
  - Resubmission of sequence waits for POST PULSE state to reconfigure

SPIDER Configuration Tool Requirements

SPIDER Configuration Tool Requirements

- It shall be a single tool to be used by Session Leader (SL) and Responsible Technician (RT), but with different viewer and permission settings;
- Human Machine Interface (HMI) shall be similar to the current SPIDER setup, reusing to the maximum extent the current design already developed;
- A new panel with the session operation limits for automatic verification of the setup validity;
- Include the functionality of loading configuration from a specific shot number or reference shot as a starting point for configuration changes;
- Add automatic verification if the loaded configuration is compatible with the present plant configuration;
- The application shall implement the synchronization between the setup tasks (both SL and RT) and the pulse sequence:
  - Shot number 100 shall be used to store the configuration in work (reference);
  - SL submits the parameter changes to RT before the pulse sequence is at CHECK STATE or READY STATE – These states shall inhibit the submission of a new configurations;
  - When SL submits a new configuration, the changes regarding the previous pulse shall be highlighted in the RT panel;
  - Submission of new configuration by RT to the model can only be made in PAS STATE;

SPIDER Configuration Tool Requirements

- The application shall be developed in Java or similar for Windows and Linux compatibility
- The definition of waveforms shall remain as an independent application, maintained by the SPIDER team (IDL tools)
- A new tab shall be created for definition of active diagnostics for the current pulse
- Regarding the diagnostics configuration:
  - A list of parameters for a specific diagnostic shall be integrated in the tool to be set by the SL
  - It shall be possible to load pre-defined tables of diagnostics for a certain type of pulse
  - It shall be also possible to change each diagnostic status in case of need by the SL
  - The SL shall be able to turn off certain diagnostics if they are not mandatory for the specific experimental program

SPIDER Configuration Tool Requirements

- Regarding the communication between SL and RT:
  - The submission of a new configuration by SL to RT shall be clearly assigned using a SUBMIT button
  - This action shall highlight all parameter changes in RT panel to be accepted
  - The parameters highlighted shall be with reference to the previous pulse
  - Special attention shall be taken to avoid that a new submission of parameters by SL can cancel the previous highlight of a changed field
  - Each parameter change (or a small group according to a certain logic) shall have an action or accept button to turn highlight off
  - Each tab title shall remain red (highlighted) as long as any parameters inside that tab is still highlighted
  - The final configuration can only be validated (submitted to OT) when there are no highlighted parameters or tabs
  - The final configuration is submitted by means of a SUBMIT button
  - The session limits shall be modified only by RT. The SL can check what the parameters are, but he cannot change them.

A long and detailed list of requirements was prepared.

Main SPIDER Configuration Tool Requirements

- Develop a single tool to be used by Session Leader (SL) and Responsible Technician (RT), but with different viewer and permission settings;
- Use a Human Machine Interface (HMI) similar to the previous SPIDER setup tool;
- Include a panel with the session operation limits for automatic verification of the setup validity;
- Add the feature of loading a configuration from a specific shot number or reference shot as a starting point for configuration changes;
- When SL submits a new configuration, the changes regarding the previous pulse (or a pulse loaded by RT) shall be highlighted in the RT panel;
- The definition of waveforms shall remain as an independent application, maintained by the SPIDER team (IDL tools)
- The application shall be developed using the maximum compatibility with the tools already in use and ITER Control Tools – MDSPLUS; EPICS; Control System Studio OPI
- Integrate the SPIDER pulse preparation cycle with the configuration and parameter approval, as well as SPIDER pulse sequence state machine.
- Introduce a pulse pre-approval method for the submission of automatic multiple pulses sequence

Integrating MDSplus and EPICS – EPICS CA

```
# ISEPS TAB

 record(stringin,"pvTest_$(pulse):ISEPS:EG_MOD_DC")  {
         field(DTYP,"Soft Channel")
         field(DESC,"ISEPS:EG_MOD_DC")
 }

  record(stringin,"pvTest_$(pulse):ISEPS:EG_MOD_FREQ")  {
         field(DTYP,"Soft Channel")
         field(DESC,"ISEPS:EG_MOD_FREQ")
 }

  record(stringin,"pvTest_$(pulse):ISEPS:EG_MOD_STATE")  {
         field(DTYP,"Soft Channel")
         field(DESC,"ISEPS:EG_MOD_STATE")
 }


 record(stringin,"pvTest_$(pulse):ISEPS:RF_MOD_DC")  {
         field(DTYP,"Soft Channel")
         field(DESC,"ISEPS:RF_MOD_DC")
 }
```

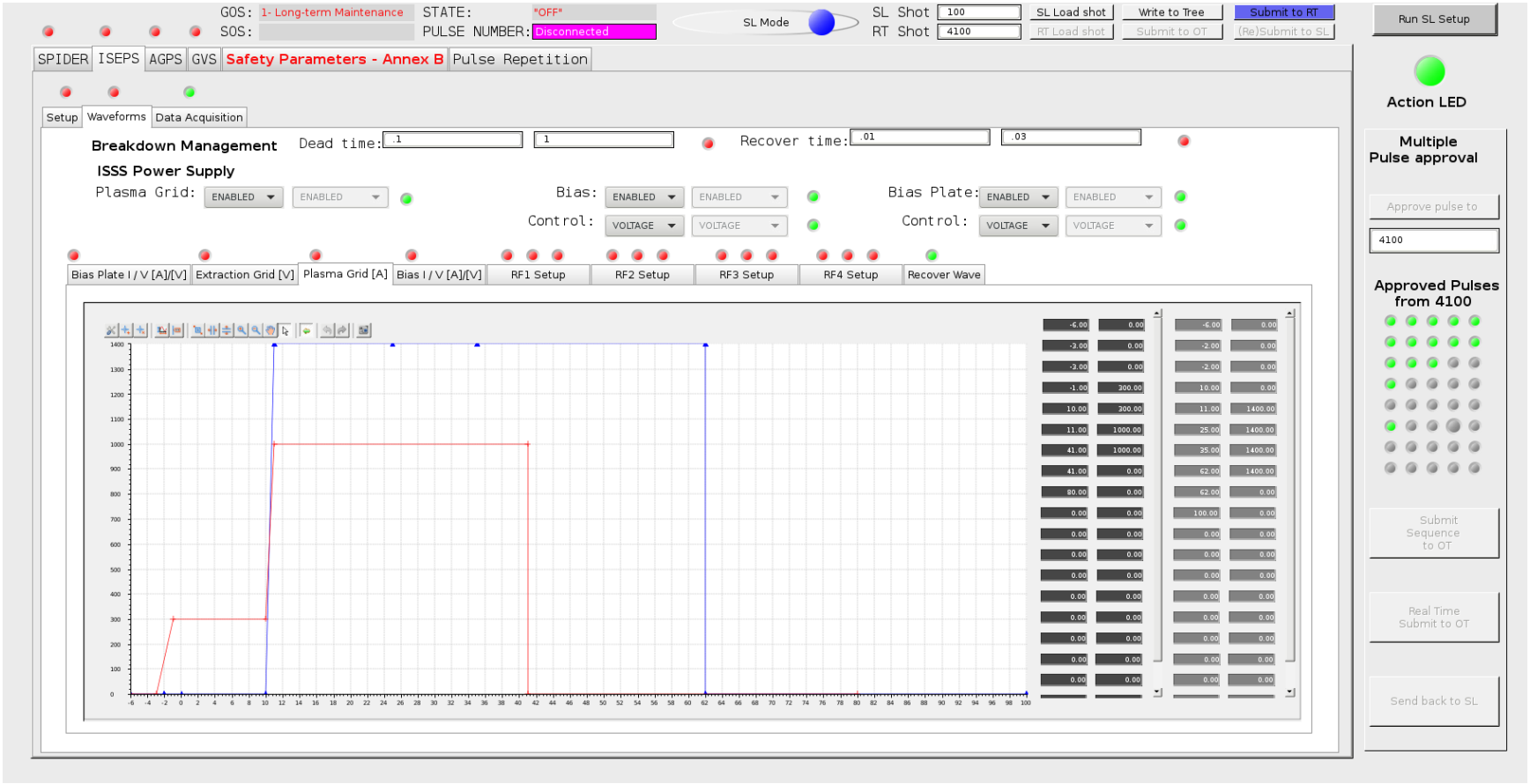
- The Experimental Physics and Industrial Control System (EPICS) has been adopted for I&C in ITER operations
- "EPICS is the software backbone of the CODAC control system." in ITER CODAC Team words
- Using a SoftIOC all necessary EPICS PVs for SPIDER configuration are created

```
#ISEPS
list.append(MDS_PVs("\\TOP:CODAS:SETUP:SPIDER_SETUP:ISEPS:EG_MOD_DC",root+"ISEPS:EG_MOD_DC"))
list.append(MDS_PVs("\\TOP:CODAS:SETUP:SPIDER_SETUP:ISEPS:EG_MOD_FREQ",root+"ISEPS:EG_MOD_FREQ"))
list.append(MDS_PVs("\\TOP:CODAS:SETUP:SPIDER_SETUP:ISEPS:EG_MOD_STATE",root+"ISEPS:EG_MOD_STATE"))
list.append(MDS_PVs("\\TOP:CODAS:SETUP:SPIDER_SETUP:ISEPS:RF_MOD_DC",root+"ISEPS:RF_MOD_DC"))
list.append(MDS_PVs("\\TOP:CODAS:SETUP:SPIDER_SETUP:ISEPS:RF_MOD_FREQ",root+"ISEPS:RF_MOD_FREQ"))
list.append(MDS_PVs("\\TOP:CODAS:SETUP:SPIDER_SETUP:ISEPS:RF_MOD_STATE",root+"ISEPS:RF_MOD_STATE"))
list.append(MDS_PVs("\\TOP:CODAS:SETUP:SPIDER_SETUP:ISEPS:FIL_ON_START",root+"ISEPS:FIL_ON_START"))
list.append(MDS_PVs("\\TOP:CODAS:SETUP:SPIDER_SETUP:ISEPS:FIL_ON_STOP",root+"ISEPS:FIL_ON_STOP"))
list.append(MDS_PVs("\\TOP:CODAS:SETUP:SPIDER_SETUP:ISEPS:FIL_STATE",root+"ISEPS:FIL_STATE"))
```

- Python scripts make the link between MDSplus database and EPICS CA
- Each MDSplus node corresponds to an EPICS PV

Integrating MDSplus and EPICS – CSS OPI

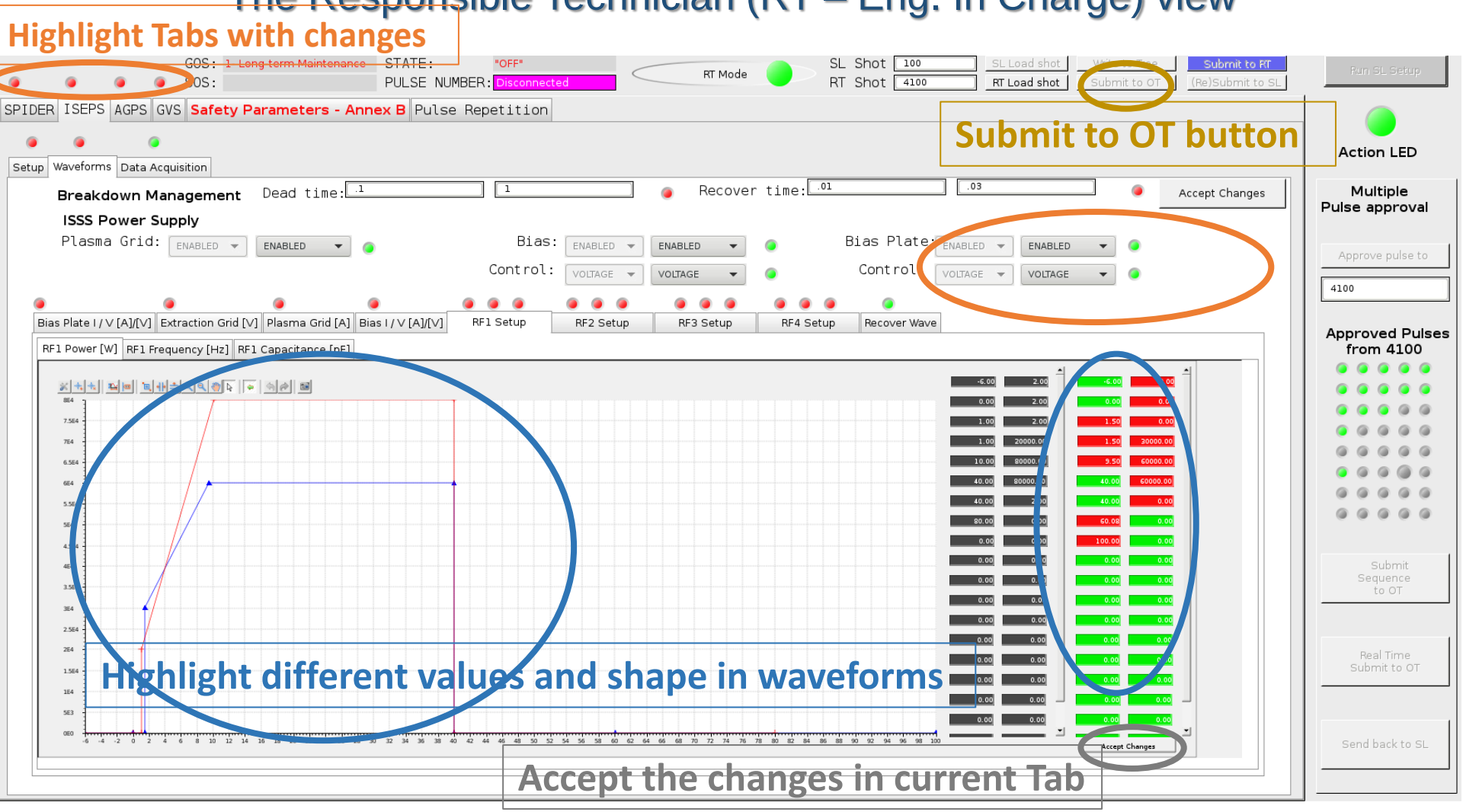
The Session Leader (SL – Scientific Coordinator) view



"Control System Studio (CS-Studio) will power ITER's dashboard, what we call the visualization layer—panels, graphs, sliders, symbols, metres and switches on the operator consoles in the ITER control room."

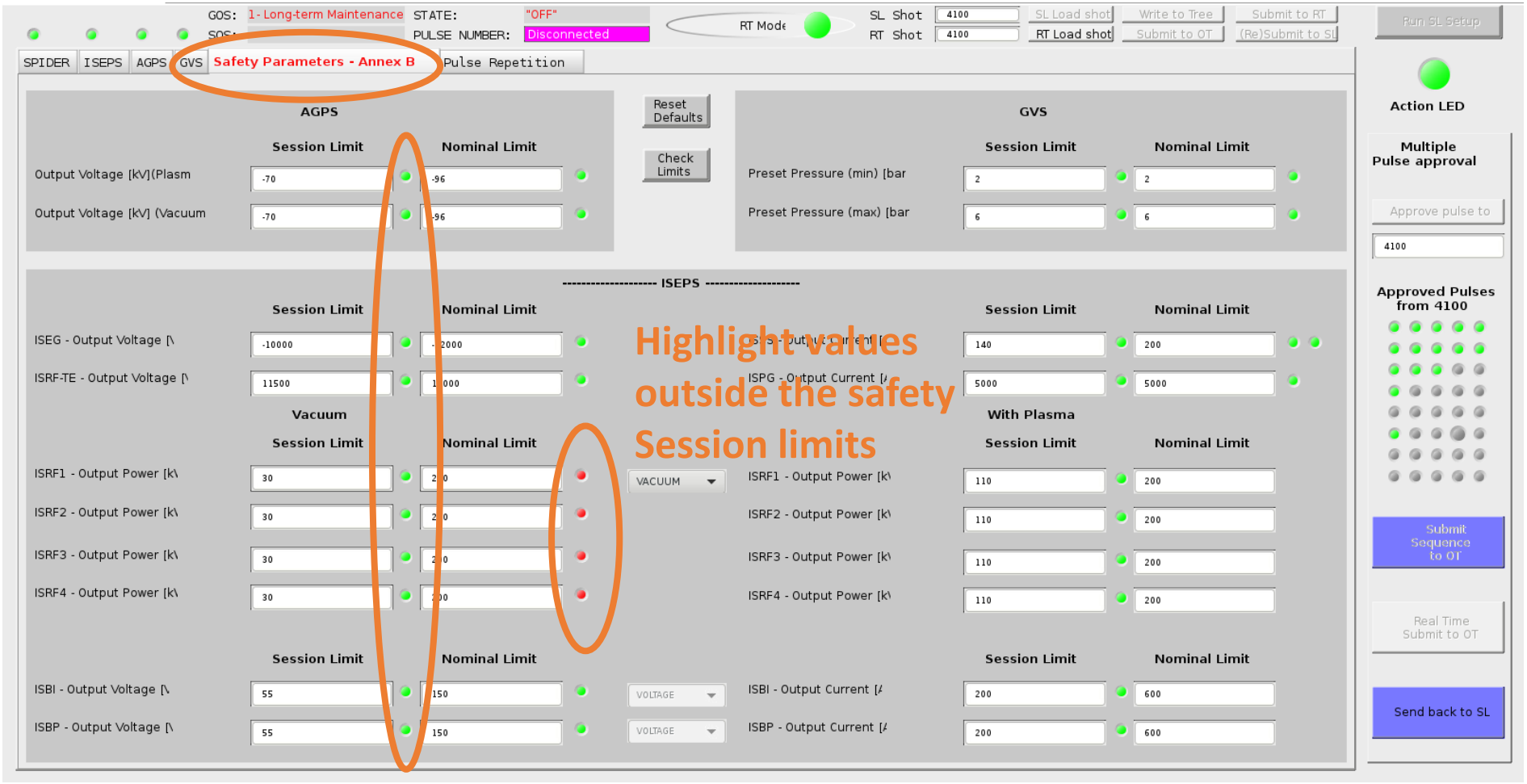
Integrating MDSplus and EPICS – CS-Studio OPI

The Responsible Technician (RT – Eng. In Charge) view



SPIDER Config. Tool: Safety Parameters Checking

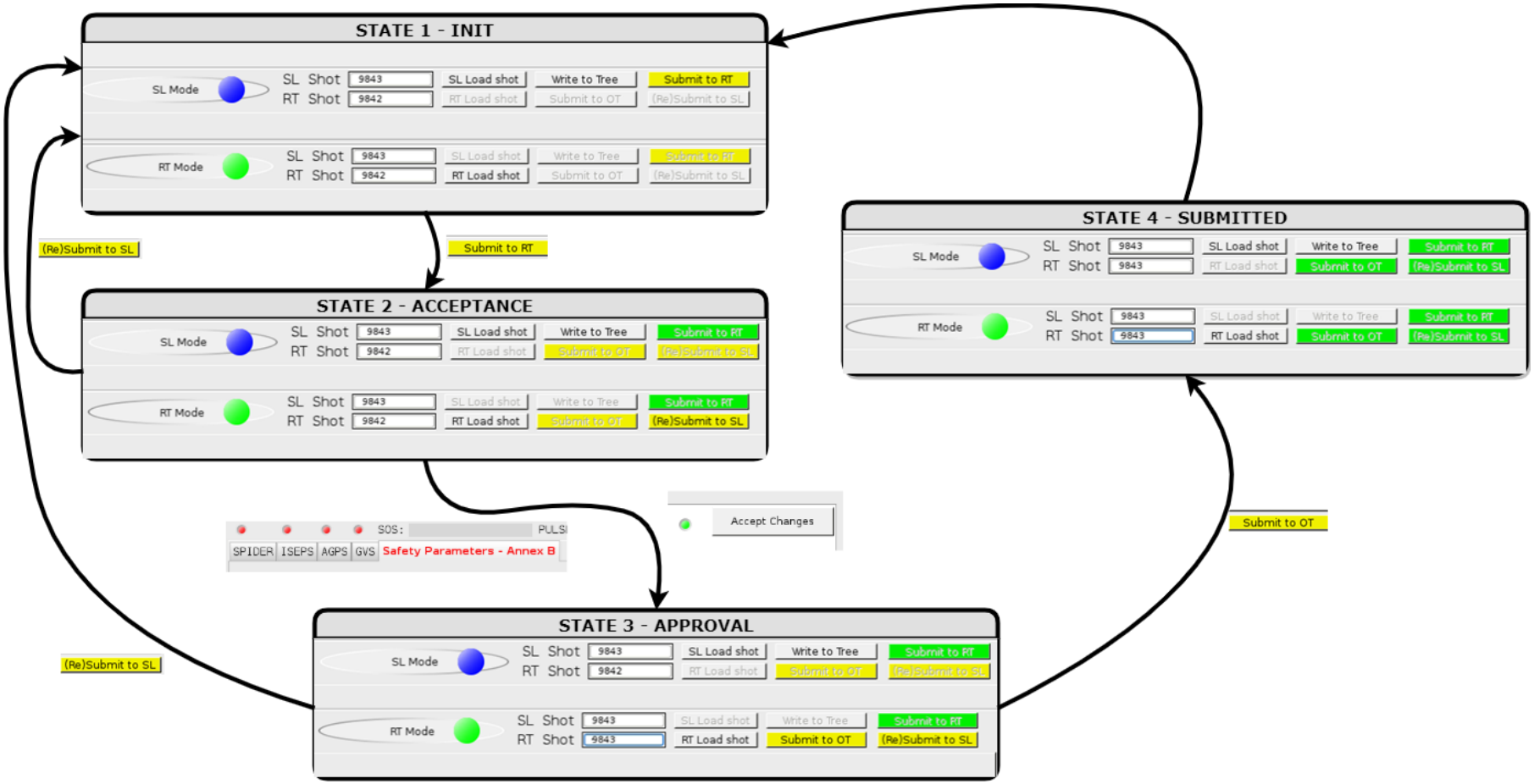
Highlight Tab with errors



Highlight values outside the safety Session limits

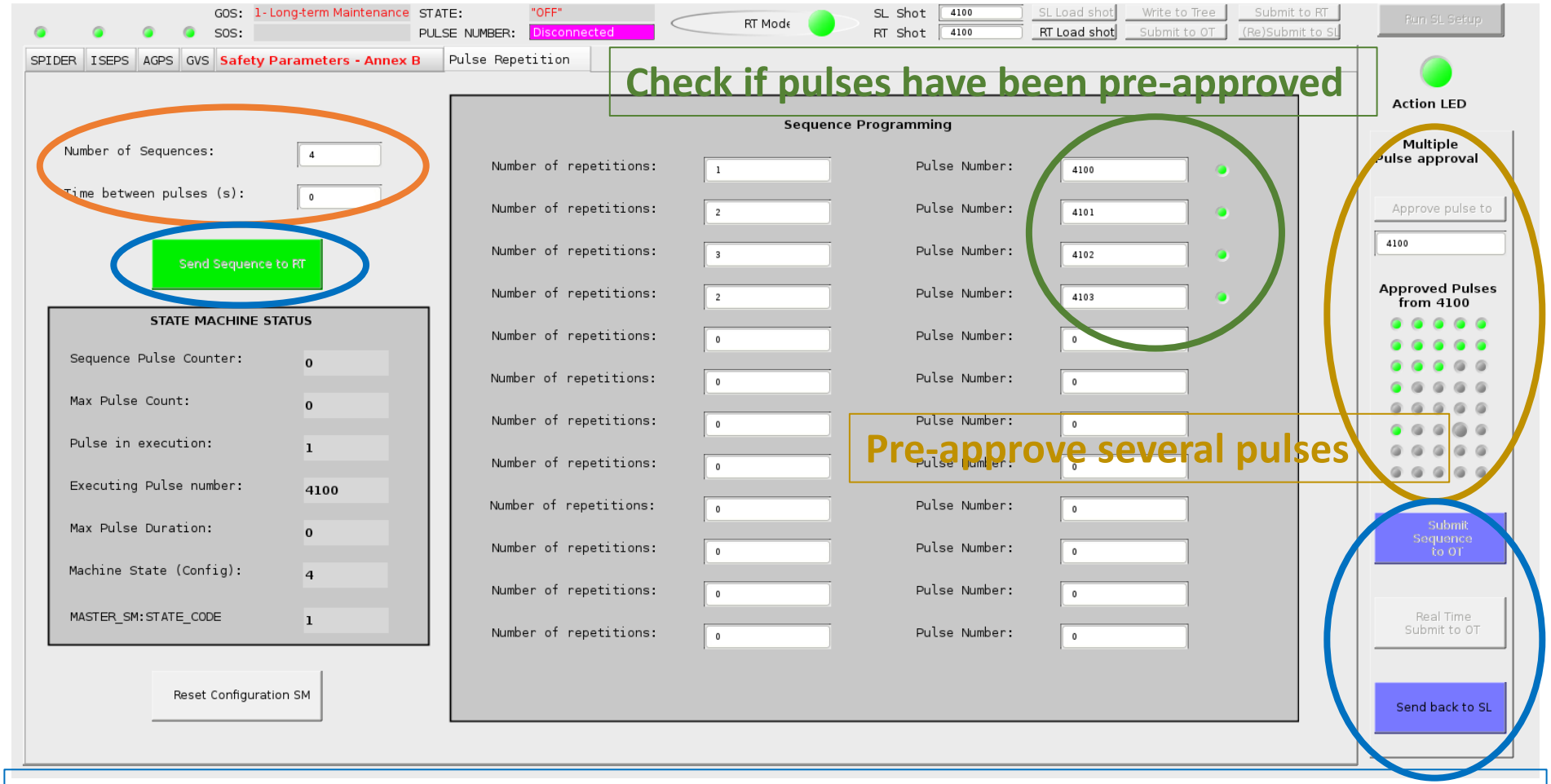
Highlight the Session Limits are inside the Nominal Limits

SPIDER Config. Tool: Single Pulse State Machine



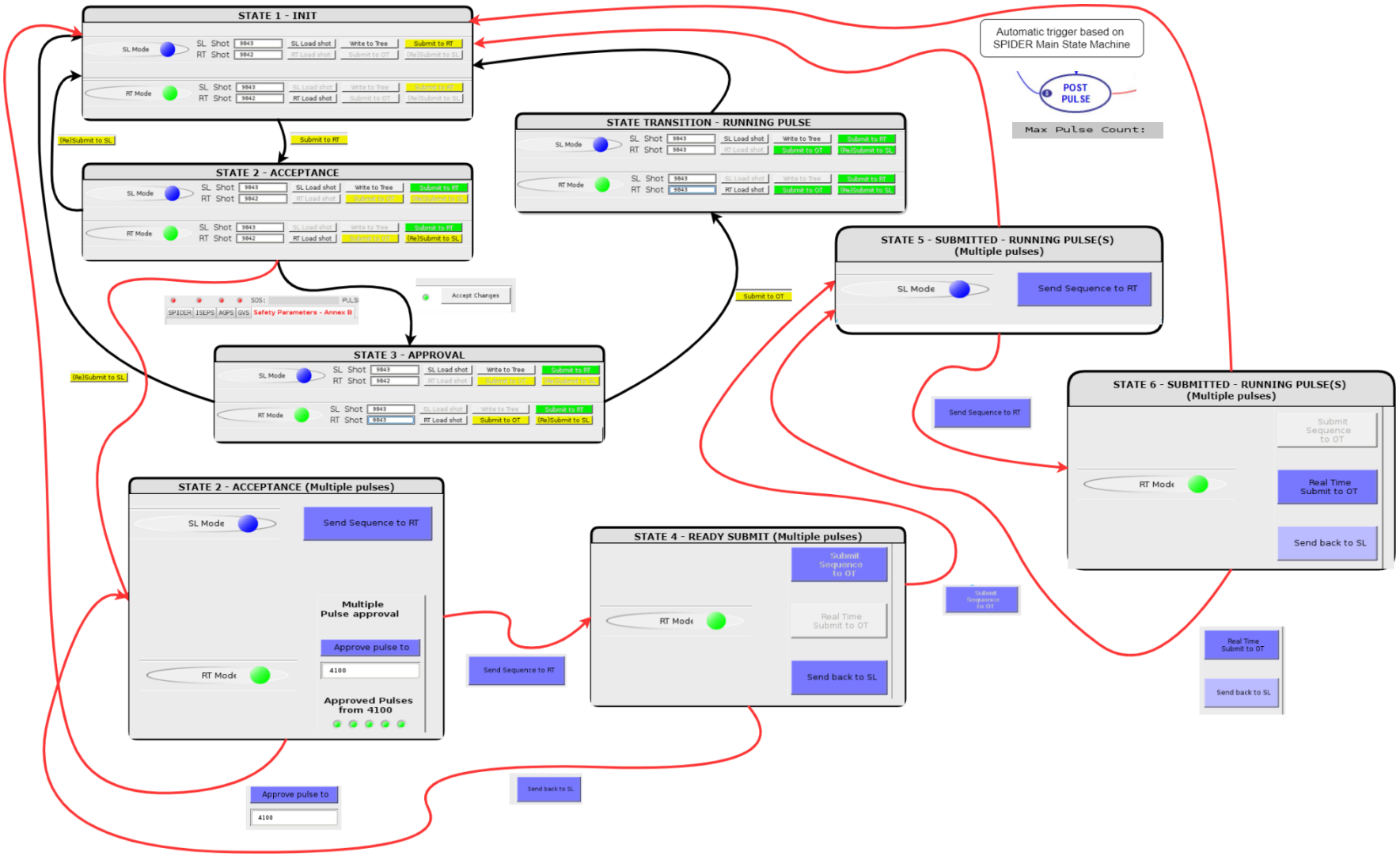
SPIDER Config. Tool: Multiple Pulse Programming

Program number of Sequences and time interval between discharges



Actuate on the State-Machine by submitting and sending actions to other operators

SPIDER Config. Tool: Multiple Pulse State Machine



SPIDER Tool – HMI importance

- Color Code (relevant for efficiency and fast operation):
  - Green button – Action completed
  - Blue button – Active action to be submitted
    - White text – disabled button: not all conditions are met or operator has no permission
    - Black text – operator can submit action
  - Grey button – Not relevant for state transition

Summary & Conclusions

- Requirement definition based on the needs of SPIDER operation has been completed
- The definition of development tools available based on ITER CODAC Plant System I&C requirements has been set
- Integration of MDSplus and EPICS for a common development environment of the SPIDER configuration HMI
- Tool implementation with the SPIDER requirements, following ITER guidelines for I&C uniformization:
  - Automatic verification of safety parameters (session limits)
  - Multiple pulse approval and automatic real-time reconfiguration of pulse sequence
  - Full integration with SPIDER pulse sequence
- Beta version of the tool has been tested and presented to operators
- Live tests @ SPIDER control room ready - after current shutdown

Acknowledgements

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