

The SPIDER Pulse Plant Configuration Environment

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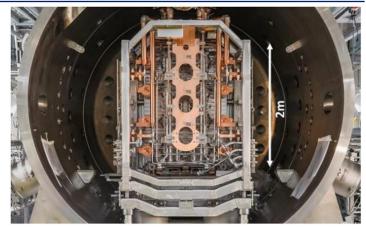
The SPIDER Experiment

- 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]

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

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The inside of the SPIDER ion source.



NBTF High Voltage Hall with

- the insulating transformer (left)
- and the high voltage deck (right)

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

🧴 jTraverser - Tree: SPIDER Shot: 95 📀 📀 😒) jTraverser - Tree: SPIDER Shot: 95 ⊙ ∧ 🤉		
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- # BREAK_REC	BP CTRL		
- # CAEN_DURAT	BP STATE		
+ CAEN_FREQ	- # BREAK_DEAD		
- # CAEN_START	- # BREAK REC		
- # NI6259_DURAT	- # CAEN_DURAT		
- <u>#</u> NI6259_FREQ	- # CAEN FREQ		
- # NI6259_START	- # CAEN START		
- <u>#</u> NI6368_DURAT	- # CS1_I_REF		
- <u>#</u> NI6368_FREQ	- # CS2_I_REF		
- <u>#</u> NI6368_START	- # EG MOD DC		
- # TRIG_SOURCE	- # EG MOD FREQ		
- 🚓 WAVE_1	- EG MOD STATE		
一 森 WAVE_2	- # FILON_START		
→ ₩AVE_3	- # FIL_ON_STOP		
- AN WAVE_4	- FIL STATE		
WAVE_5	- # FIL_V_REF		
- A WAVE_6	- # ISRF TE V		
- A WAVE_7	- # NI6259 DURAT		
- 🚓 WAVE_8	# NI6259 FREQ		
A WAVE_REC	# NI6259 START		
← 嬴 GVS	# NI6368_DURAT		
- E GAS_TYPE	# NI6368 FREQ		
# PRESET_PRES	# NI6368 START		
TANK	- PG_STATE		
+ VC2001 TURNS	# RF_MOD_DC		
- # VC3001_TURNS	- # RF MOD FREQ		
- <u># VC3002_TURNS</u>	RF_MOD_STATE		
— 嬴 WAVE_1 — 嬴 WAVE 2	F REG MODE		
- 嬴 WAVE 3	← 嬴 WAVE 1		
a WAVE_3	← 点 WAVE 10		
森 WAVE_4	← 点 WAVE 11		
- AT WAVE 6	← 森 WAVE 12		
- AN WAVE_0	∽ 嬴 WAVE 13		
AT WAVE 8	← 森 WAVE 14		
► ♣ ISEPS	← 森 WAVE 15		
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Tree: SPIDER Shot: 95			
THEE, SFIDEN SHOL, 95	Tree: SPIDER Shot: 95		

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

🌼 jTraverser - Tree: SPIDER Shot: 95 📀 🔿 🏵)
File Edit Data Customize	
- 嬴 CONFIG	•
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- SPIDER_SETUP	
∽ 嬴 AGPS	
∽ 嬴 GVS	
► 森 ISEPS	
中 点 SPIDER	
<u> </u>	
- # RT_START	
= # RT_STOP	
- # T_START_SP	
- # WREF_START	
# WREF_STOP	
→ 点 IIMING ・ 点 PLANTS	
一	
- 森 INTERLOCK	
- A MACHINE	
- A POWER	
- A PRIMA	
- A SAFETY	-
Free: SPIDER Shot: 95	1





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MDSplus Device Setup – SPIDER SL Configuration Tool

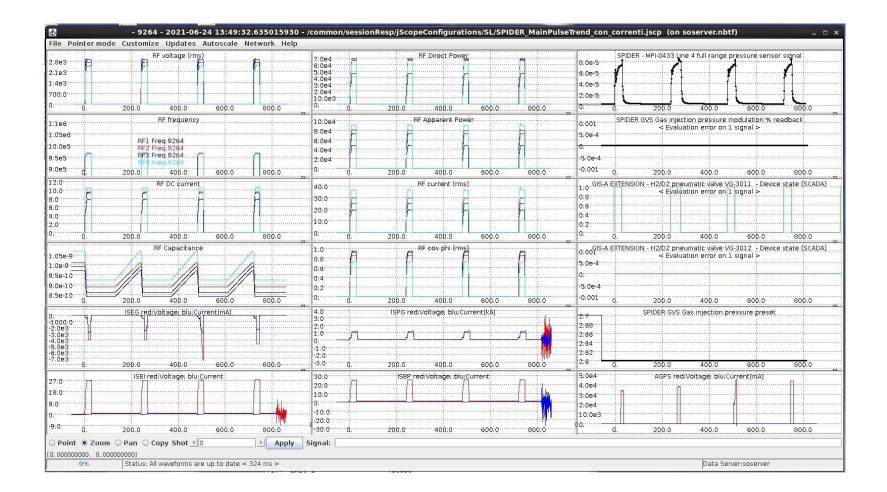
<u>ی</u>	SPIDER Experiment S	Setup \SPIDER::TOP.CODAS	SETUP:SPIDER_SETU	JP (on soserver.nb	tf) ×
SPIDER ISEPS	AGPS GVS Safety F	Parameters - Annex B			
Setup Wavef	orms Data Acquisition				
Breakdown Mar	nagement				
	Dead time Time: 1	Re	cover time: .03]
ISSS Power Sup	ply				
Plasm	a Grid: ENABLED 💌	Bias: ENABLED 🔻 Contr	rol: VOLTAGE 👻	Bias Plate: EM	ABLED -
Filament Bias [Recover Wave		
Bias P	late I / V [A]/[V]	Extraction Grid [V]	Plasma Gr	id [A]	Bias I/V [A]/[V]
RF1 Power [W]	RF1 Frequeny [Hz] RF	1 Capacitance [pF]			
		Max Y: 150000.0 🗌 Edi	it Update		
					Time Value
					-6 0 •
1.2e5					. 1.5 0
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8.0e4					40 0
4.0e4					
Ψ					
17					
		Ok Apply Res	et Cancel		

- 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

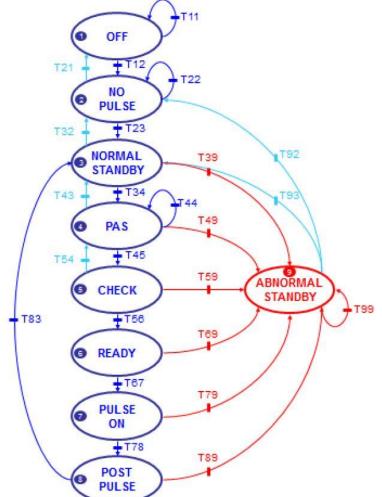








SPIDER Pulse Sequence



- 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 <u>similar to</u> 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;
 - o Submission of new configuration by RT to the model can only be made in PAS STATE;



SPIDER Configuration Tool Requirements

- Regarding the communication between SL and RT:
 - $\circ~$ The submission of a new configuration by SL to RT shall be clearly assigned using a SUBMIT button
 - o This action shall highlight all parameter changes in RT panel to be accepted
 - o 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
 - $\,\circ\,\,$ Each tab title shall remain red (highlighted) as long as any parameters inside that tab is still highlighted
 - $\,\circ\,$ The final configuration can only be validated (submitted to OT) when there are no highlighted parameters or tabs
 - $\circ\;$ The final configuration is submitted by means of a SUBMIT button
 - $\,\circ\,$ The session limits shall be modified only by RT. The SL can check what the parameters are, but he cannot change them.

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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
 - $\circ\,$ It shall be possible to load pre-defined tables of diagnostics for a certain type of pulse
 - $\,\circ\,$ 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



A long and detailed list of requirements was prepared.



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

- 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

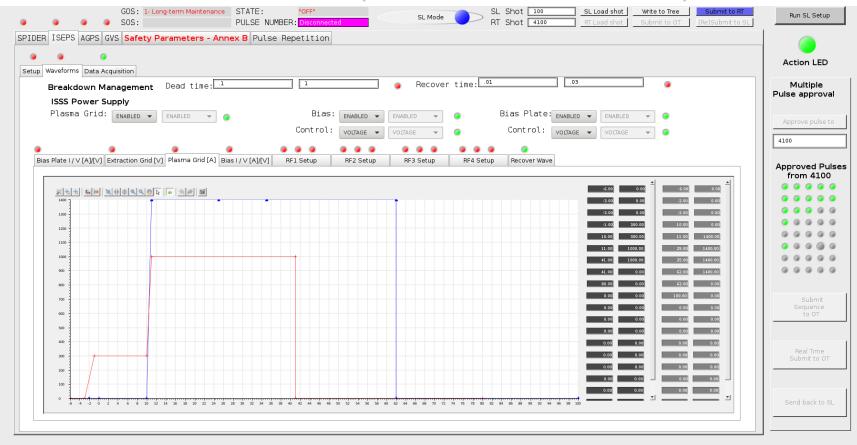
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list.append(MDS_PVs("\\TOP:CODAS:SETUP:SPIDER_SETUP:ISEPS:EG_MOD_DC",root+"ISEPS:EG_MOD_DC"))
list.append(MDS_PVs("\\TOP:CODAS:SETUP:SPIDER_SETUP:ISEPS:EG_MOD_FREQ",root+"ISEPS:EG_MOD_FREQ"))
list.append(MDS_PVs("\\TOP:CODAS:SETUP:SPIDER_SETUP:ISEPS:RF_MOD_DC",root+"ISEPS:RF_MOD_DC"))
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_FREQ",root+"ISEPS:RF_MOD_FREQ"))
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





"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."

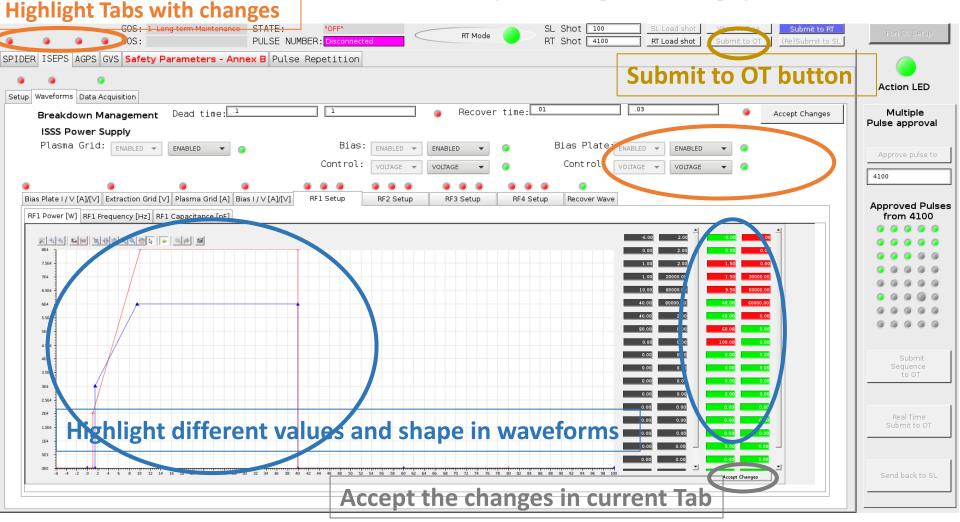






Integrating MDSplus and EPICS – CS-Studio OPI

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



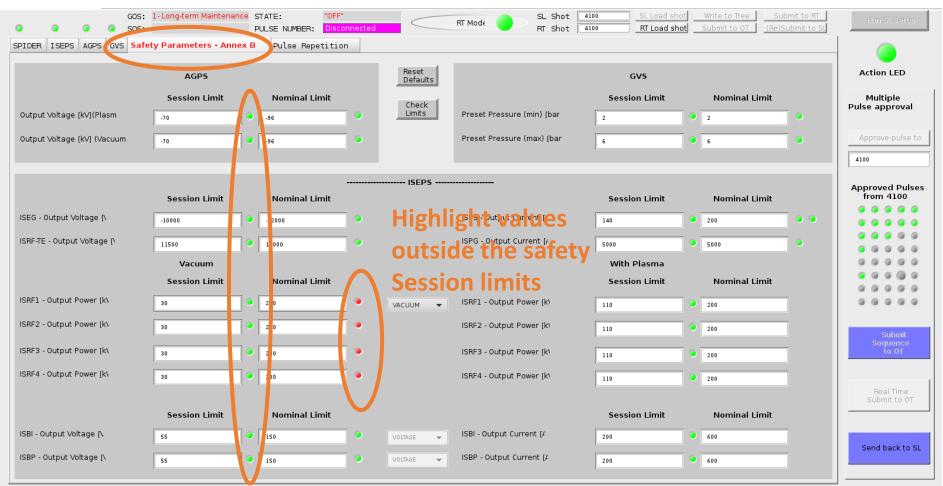
CONSORZIO RFX



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SPIDER Config. Tool: Safety Parameters Checking

Highlight Tab with errors



Highlight the Session Limits are inside the Nominal Limits

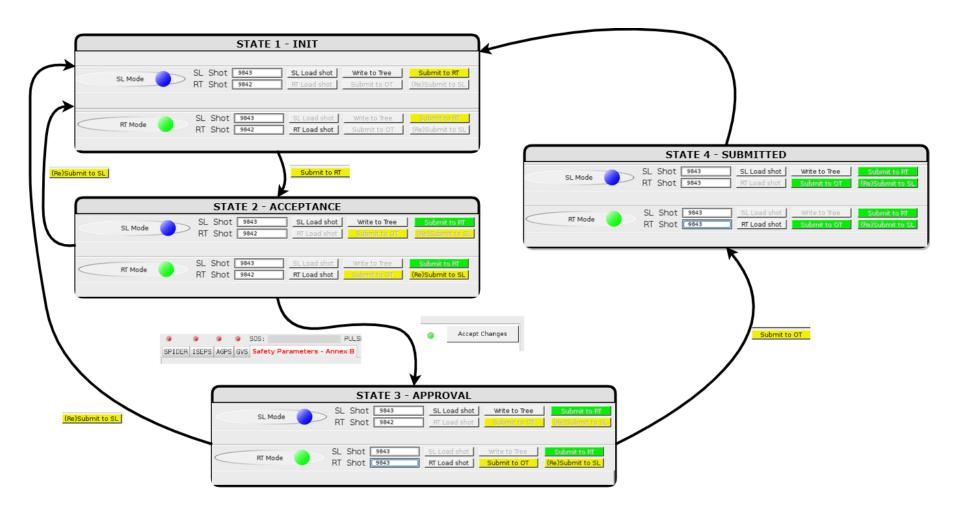






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SPIDER Config. Tool: Single Pulse State Machine









SPIDER Config. Tool: Multiple Pulse Programming

Program number of Sequences and time interval between discharges GOS: 1-Long-term Maintenance STATE: 4100 SL Shot RT Mode SOS: PULSE NUMBER: RT Shot 4100 RT Load shot SPIDER ISEPS AGPS GVS Safety Parameters - Annex B Pulse Repetition <u>Check if pulses have been pre-approved</u> Action LED Sequence Programming Multiple Number of Sequences: 4 ulse approval Number of repetitions: Pulse Number: 4100 1 ime between pulses (s): 0 Number of repetitions: Pulse Number: 4101 2 4100 Number of repetitions: Pulse Number: 3 4102 Approved Pulses Number of repetitions: Pulse Number: 2 4103 from 4100 STATE MACHINE STATUS Number of repetitions: Pulse Number: 0 Sequence Pulse Counter: 0 Number of repetitions: Pulse Number: 0 0 Max Pulse Count: 0 Number of repetitions: Pulse Number: 0 Pulse in execution: *re sever*al pulses 1 e-appr Number of repetitions: 0 Executing Pulse number: 4100 Number of repetitions: Pulse Number: 0 0 Max Pulse Duration: 0 Number of repetitions: Pulse Number: Machine State (Config): 4 Number of repetitions: Pulse Number: 0 MASTER SM:STATE CODE 1 Number of repetitions: Pulse Number: 0 0 Reset Configuration SM Send back to SL

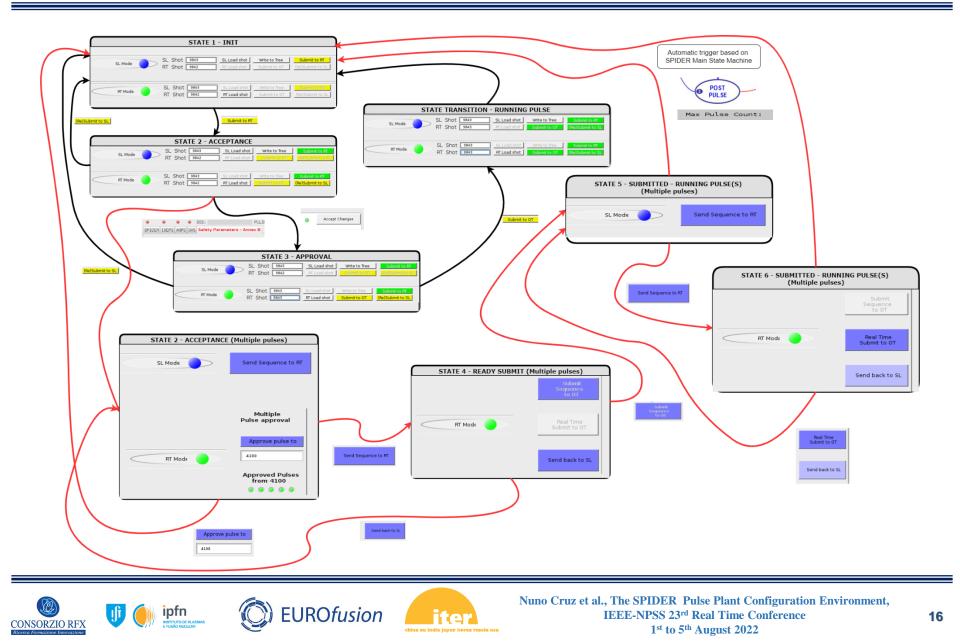
Actuate on the State-Machine by submitting and sending actions to other operators







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

<	SL Mode	SL Shot RT Shot		SL Load shot RT Load shot	Write to Tree Submit to OT	Submit to RT (Re)Submit to SL
<	RT Mode	SL Shot RT Shot		SL Load shot RT Load shot	Write to Tree Submit to OT	Submit to RT (Re)Submit to SL
RFX	ipfn errubo nacasas	EUROfusion	thina w India japan Korea russia usa		The SPIDER Pulse Plant EEE-NPSS 23 rd Real Tim 1 st to 5 th August 2	

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



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