

A Plant System Configuration Tool based on MDSplus and EPICS for the ITER Neutral Beam Test Facility experiment SPIDER

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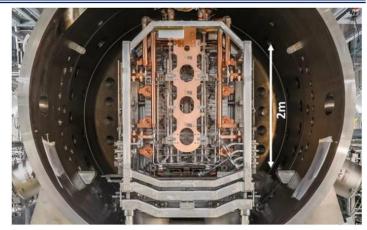
The SPIDER Experiment

- 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 – Present Situation

- SPIDER parameters are 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) can load previous setup from an executed shot or reference shot;
- SL can check all the configuration using jScope, with all the waveforms;
- An external tool can create the long pulse setup in IDL and store it in a reference shot;
- Responsible Technician (RT) can only verify the setup in paper and in jScope;
- After RT approval, Operation Technician (OT) loads the config from reference shot 100 to the SPIDER model setup, via shell command;
- Some consistency check on the configuration is made by the loading tool;
- This is a time consuming operation without automatic verification or feedback to the SL;
- It is foreseen to develop a solution similar to the one implemented in the past for RFX Operations.







MDSplus SPIDER MDStree & Data Structure

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- # BREAK_DEAD	
+ 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
- <u>#</u> NI6259_START	# CAEN START
<u>+ NI6368_DURAT</u>	# CS1_I_REF
<u># NI6368_FREQ</u>	# CS2_I_REF
	# EG MOD DC
- <u>#</u> TRIG_SOURCE	# EG MOD FREQ
- 💀 WAVE_1	EG_MOD_STATE
- A WAVE_2	# FIL_ON_START
- 嬴 WAVE_3 =	- # FIL_ON_STOP
- 嬴 WAVE_4	- E FIL STATE
A WAVE 5	# FIL_V REF
一	- # ISRF TE V
一	- # NI6259 DURAT
- A WAVE_8 - A WAVE_REC	- # NI6259_FREQ
← क़ GVS	# NI6259_START
GAS TYPE	- # NI6368_DURAT
- # PRESET PRES	- # NI6368_FREQ
	# NI6368_START
- # TRIG SOURCE	- E PG_STATE
- # VC3001 TURNS	- # RF_MOD_DC
- # VC3002_TURNS	- # RF_MOD_FREQ
- 嬴 WAVE 1	- E RF_MOD_STATE
- A WAVE 2	- E RF_REG_MODE
- 嬴 WAVE 3	► 点: WAVE_1
— 标 WAVE 4	► 点 WAVE_10
- 森 WAVE_5	► 点 WAVE_11
— 森 WAVE_6	► 点 WAVE_12
— 森 WAVE_7	► 点 WAVE_13
wave_8	► 点动 WAVE_14
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Tree: SPIDER Shot: 95	小小小小小小小小小小小小小小小小小小小小小小小小小小小小小小小小小小小小小
	THEE, SPIDER SHOL: 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 📀 \land 🗵	
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<u>#</u> RT_FREQ	
<u># RT_START</u>	
- # RT_STOP	
# TIME_OF_INTE	
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MDSplus Device Setup – SPIDER SL Configuration Tool

SPIDER Experiment Setup \SPIDER::TOP.CODAS.SETUP:SPIDER_SETUP	×
SPIDER ISEPS AGPS GVS	
Setup Waveforms Data Acquisition	
Breakdown Management	
Dead time Time: 02 Recover time: 01	
ISSS Power Supply	
Plasma Grid: ENABLED VOLTAGE Bias Plate: ENABLED Control: VOLTAGE Bias Plate: ENABLED Control	ol: VOLTAGE 🔻
Bias Plate I / V [A]/[V] Extraction Grid [V] Plasma Grid [A] Bias I/V [A]/[V] RF1 Setup RF2 Setup RF3 Setup RF4 Setup Rever Wave	
RF2 Power [W] RF2 Frequeny [Hz] RF2 Capacitance [pF]	
Max Y: 150000.0 🗌 Edit Update	
10.044	Time Value -6 0 ● 0 0 20000 0 20000 0 0 20000 0 0 20000 0 0 110000 60 60 0 0 100 0 □
Ok Apply Reset 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

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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
 - o 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.







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

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Integrating MDSplus and EPICS – CSS OPI

The Session Leader (SL) view

	SL Mode	Submit to TO
EPS AGPS GVS Tab 4 Experimental Sandbox		
forms Data Acquisition		
akdown Management Dead time: .02	Recover time: .01	
	Necover cline01	
S Power Supply		
asma Grid: ENABLED	Bias: ENABLED : Bias F	late: ENABLED :
	Control: VOLTAGE Cont	rol: VOLTAGE
te I / V [A]/[V] Extraction Grid [V] Plasma Grid [A] Bias I / V [A]/[V] RF1	Setup DE2 Setup DE3 Setup DE4 Setup Becover Wave	
	setup Rrz setup Rrs setup Rr4 setup Recover wave	
wer [W] RF1 Frequency [Hz] RF1 Capacitance [pF]		
		4.000 0.000
800 <u>0.000</u>		2.000
500 0.000 mx		1.500 0.000
500 20000 000 A.S.A.		1.500 20000.000
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00 0.000 HA -		0.000 0.000
		0.000 0.000
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800 <u>880</u>		0.000 0.000
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2.000 2.000		0.000 0.000
00 0.000 1.044		8.000 8.000
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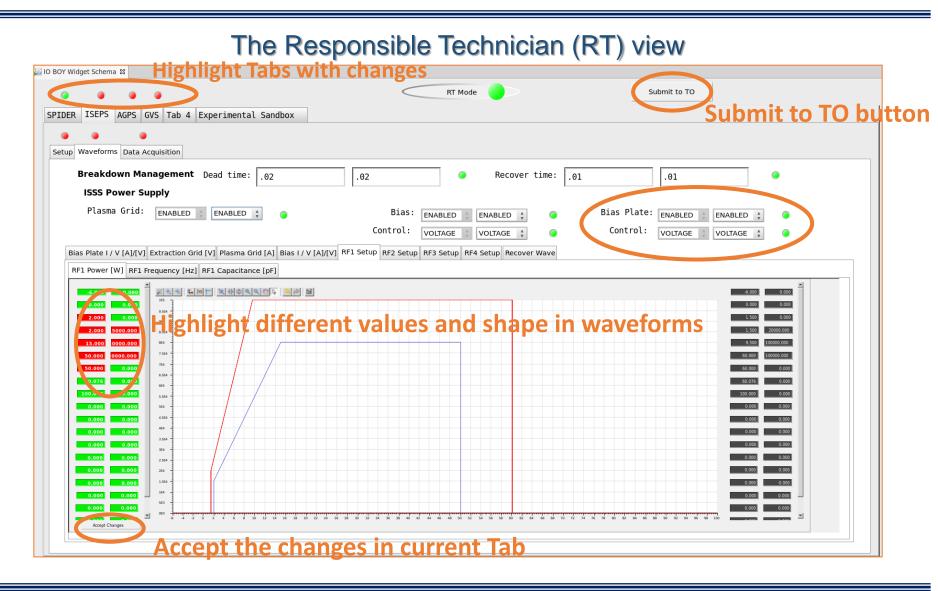
"Control System Studio (CS-Studio) will power ITER's dashboard, what we call the visualization layer panels, graphs, sliders, symbols, metres and switches on the operator consoles in the ITER control room."







Integrating MDSplus and EPICS – CS-Studio OPI









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
- Completed the design for the Integration of MDSplus and EPICS for a common development environment of the SPIDER configuration HMI
- Implementation of the configuration tool that takes into consideration the SPIDER requirements, according to the ITER guidelines for I&C uniformization
- Alpha version of the tool to be released this month for the first live tests @ SPIDER control room







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