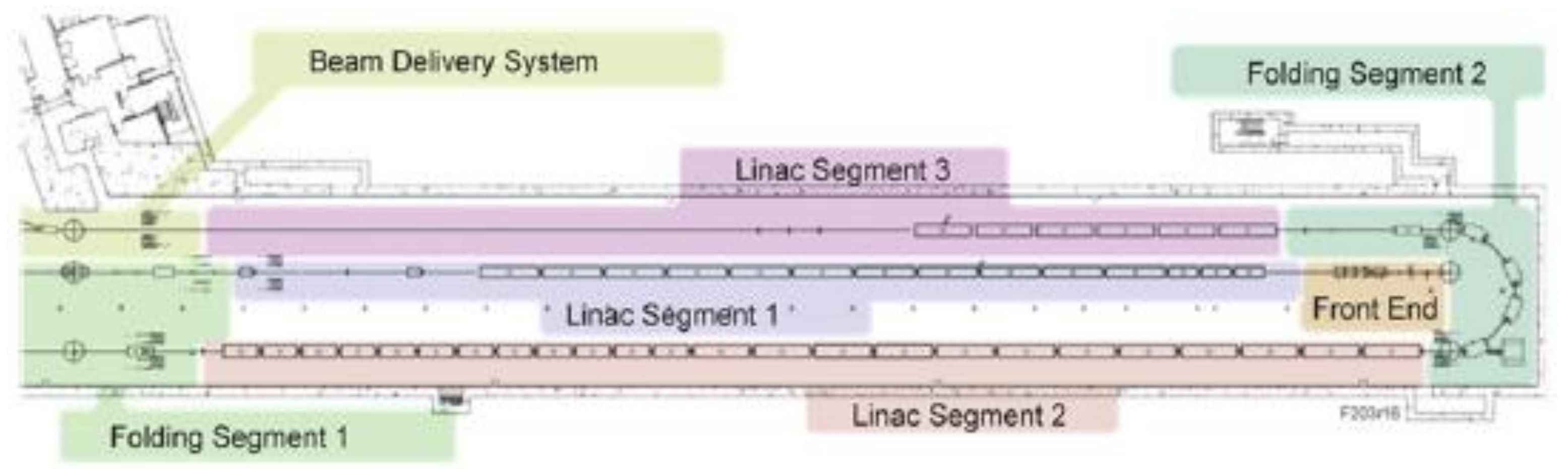


FRIB RF EXPERT APPLICATION USING PYTHON

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FRIB Linac



The FRIB linac consists of

- room temperature front end devices:
 - Low Energy Beam Transport (LEBT)
 - Multi Harmonic Buncher (MHB)
 - Radio Frequency Quadrupole (RFQ)
 - Medium Energy Beam Transport (MEBT)

- 104 Quarter-Wave Resonators (QWR)

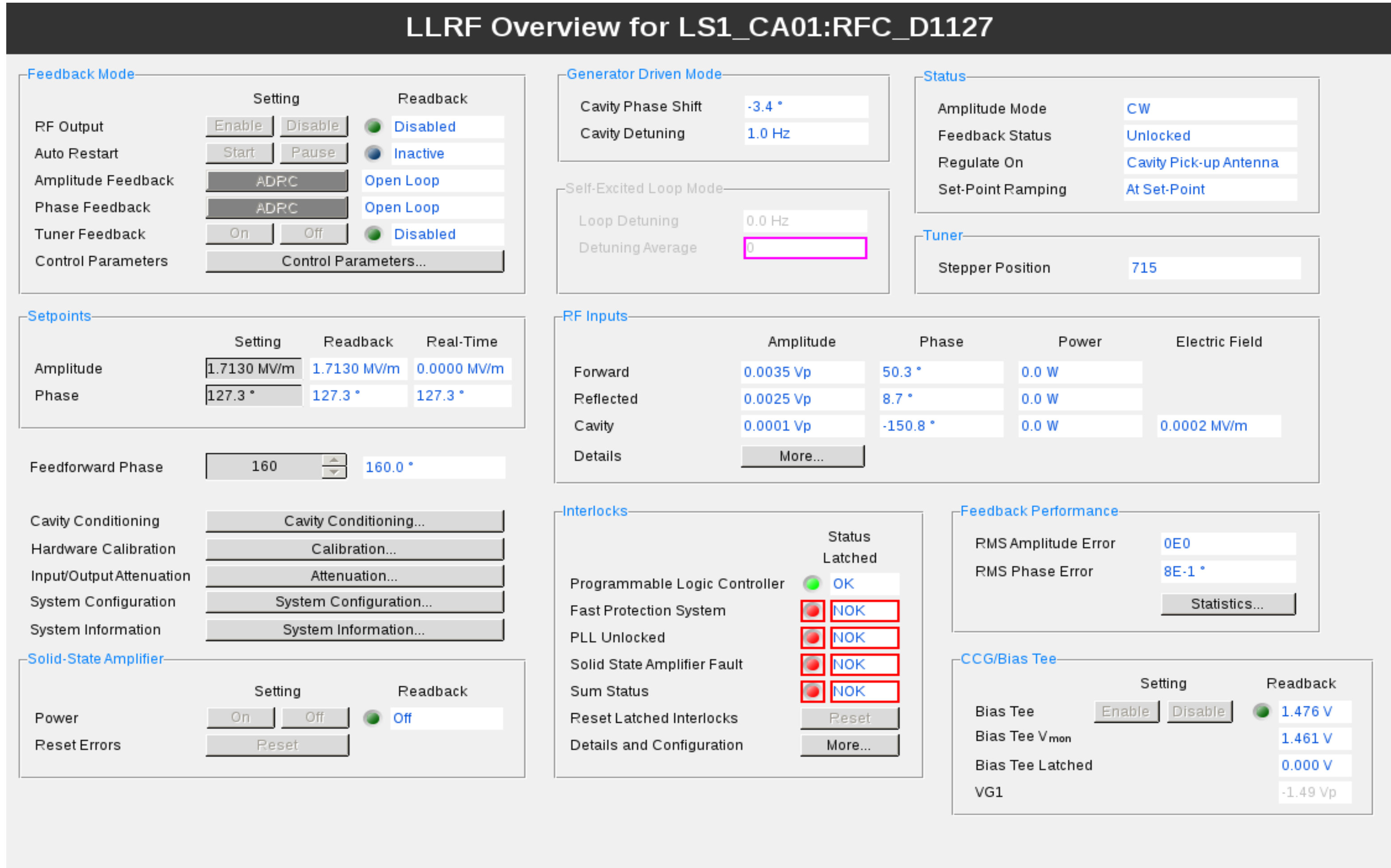
- 220 Half-Wave Resonators (HWR)

- CS-Studio engineering screens have been developed for users to access all RF parameters related to Low Level Radio Frequency (LLRF) Controller and Amplifier

- Each RF system contains around **400 process variables** (PV) including parameters for interlocks, control parameters, cavity conditioning, calibration, attenuation, system configuration etc.

- All these PVs are accessible using **Experimental Physics and Industrial Control System** (EPICS) channels. IOC driver handles read/ write actions to these PVs

Resonator	QWR1	QWR2	HWR1	HWR2
β	0.041	0.085	0.29	0.53
f (MHz)	80.5	80.5	322	322
No. of cavities	12	92	72	148
Tuner	Stepper	Stepper	Pneumatic	Pneumatic



Python Application

- Python offers several convenient features for scientific and engineering programming. The Python EPICS package (**PyEpics**) is useful to interact with EPICS channel access PVs.
 - 'import epics'
- Qt Designer** is the Qt tool helpful in designing and building graphical user interfaces. Utilities from PyQt library helps to generate Python files
 - Built-in widgets and forms
 - XML '.ui' format to store design files
 - 'uic' module to convert to C++ code
 - 'pyuic' module to convert to Python code
 - 'pyuic5 filename.ui -o filename.py'
- Several python scripts have been developed for RF commissioning at FRIB. "FRIB RF Expert" application let users perform mass action to apply to multiple LLRF and amplifier systems. This application serves as main file and all developed Python scripts are nested under it.

Linac Segment	System Type	CM	Cavities
Linac Segment 1	CA	3	12
Linac Segment 1	CB	11	88
Folding Segment 1	CH	1	4
Linac Segment 2	CC	12	72
Linac Segment 2	CD	12	96
Folding Segment 2	CG	1	4
Linac Segment 3	CD	6	48

- System:** Selection based on cavity number, cryomodule number, system type or linac segment type. Script searches for keyword in database where all device names for LLRF controller and Amplifier are stored

- Action:** Options to turn On/ Off, clear/reset interlocks for LLRF controller and amplifier

- PV:** Manually input PV name and Value

- Initialize LLRF:** Useful to setup parameters such as cavity type, attenuation, interlocks, control parameters etc. to initial values before running RF for first time

- Check Readbacks:** useful to make sure all set-points and readbacks match and there is no discrepancy in values

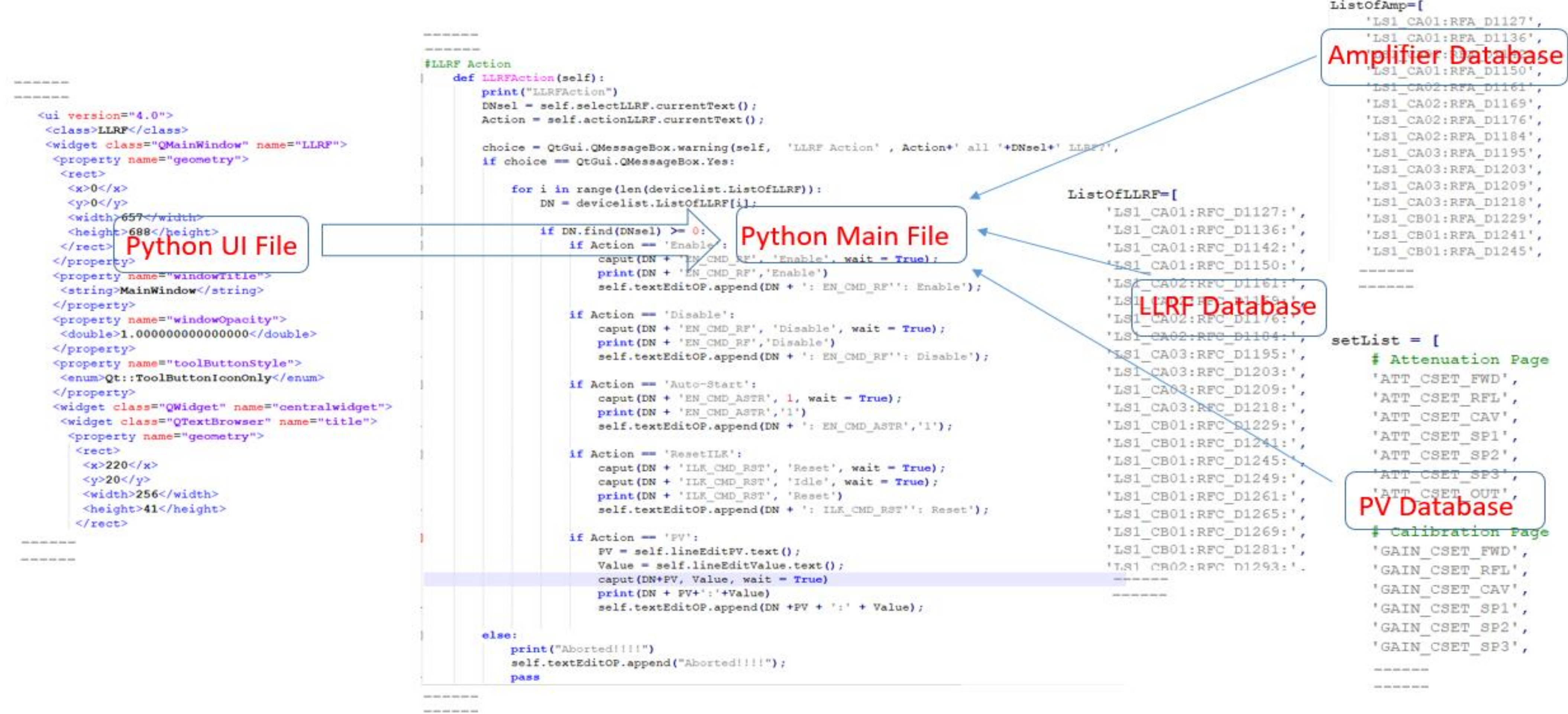
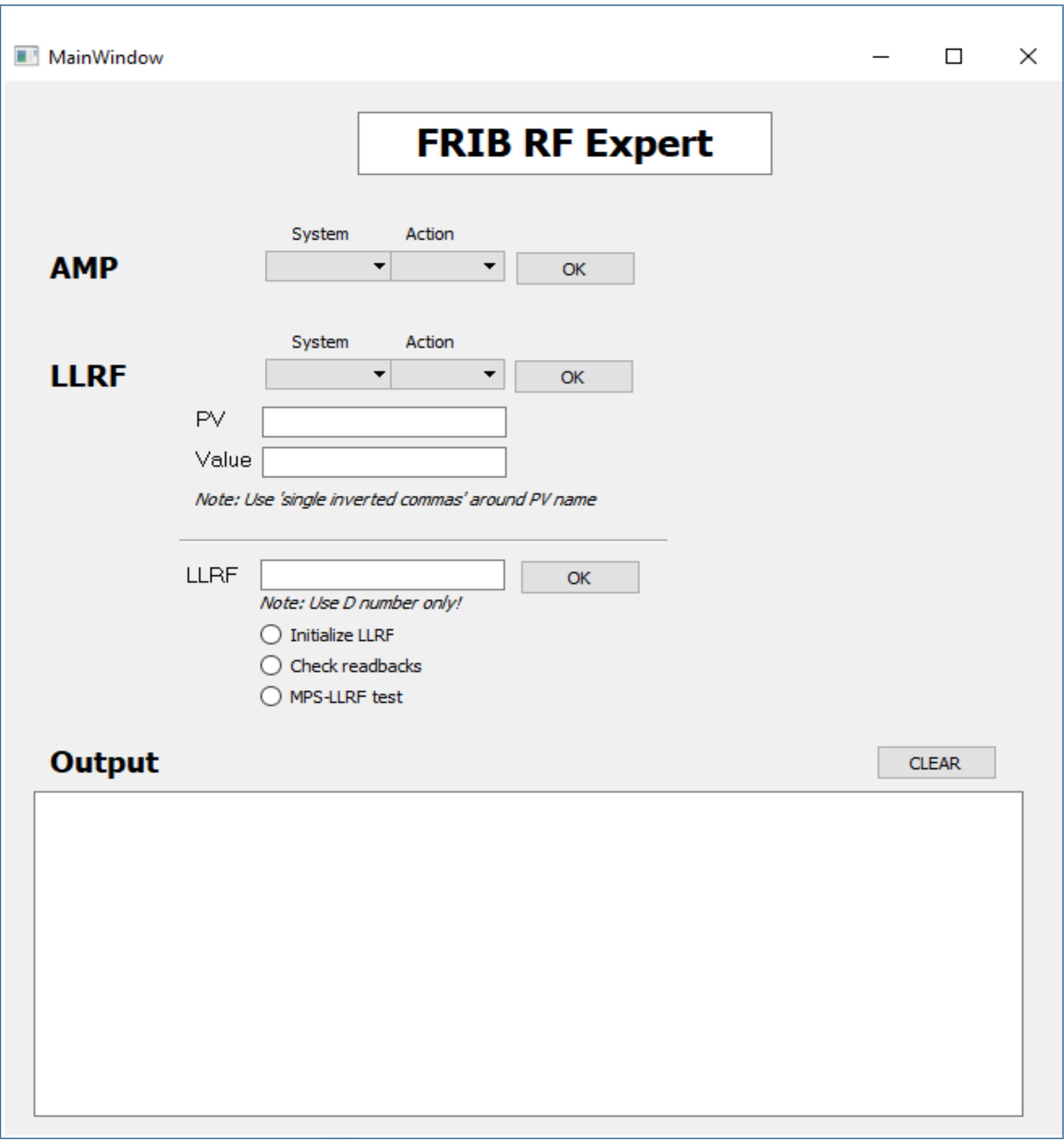
- MPS-LLRF test:** Useful to run test between LLRF controller and Machine Protection System (MPS)

- Once any combination of system and action are selected, it shows a pop-up message to verify user actions

- Output window shows device names, PV names and values it has changed

- Python script is an easy way to prototype any state machine quickly and test the logic**

- Once developed and tested, script's logic can be transferred to **State Notation Language (SNL)** and implement on IOC driver . To provide most channel access security, it is recommended to implement state machines on IOC driver.



State Notation Language (SNL)

- Allows programming of sequential state-oriented operations to run in the IOC
- Can implement complicated algorithm, Implement complex closed loop control schemes
- C code can be embedded as part of the sequence

- Channel Access security

- Watch for likely fault modes that are hard to detect via alarms

- Requires IOC restart for changes

- Coordinate control of multiple devices

- File access can be implemented as part of the sequence

Future Work

- Transitioning this application to State Notation Language (SNL) and implement on IOC driver to add channel access security



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