THE DEVELOPMENT OF AUTOMATIC SEQUENCES FOR THE RF AND CRYOGENIC SYSTEMS AT THE SPALLATION NEUTRON SOURCE *

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ABSTRACT

Automatic sequences both ease the task of operating a complex machine and ensure procedural consistency. At the Spallation Neutron Source project (SNS), a set of automatic sequences have been developed to perform the start up and shut down of the high power RF systems. Similarly, sequences have been developed to perform backfill, pump down, automatic valve control and energy management in the cryogenic system. The sequences run on Linux soft input-output controllers (IOCs), which are similar to ordinary EPICS (Experimental Physics and Industrial Control System) IOCs in terms of data sharing with other EPICS processes, but which share a Linux processor with other such processors. Each sequence waits for a command from an operator console and starts the corresponding set of instructions, allowing operators to follow the sequences either from an overview screen or from detail screens. We describe each system and our operational experience with it.

PROJECT DESCRIPTION

The SNS project is a partnership involving six DOE national laboratories: Argonne, Brookhaven, Jefferson, Lawrence Berkeley, Los Alamos and Oak Ridge. The status of the project is described in more detail on the web [1] and elsewhere [2].

HIGH POWER RF STARTUP AND SHUTDOWN

The SNS Linac High Power RF system comprises 14 modulators, 25 transmitters and 92 klystrons which supply RF power to 92 cavities (11 normal conducting and 81 superconducting) [3]. Operators are able to start up all of these systems using a single button. The sequences send commands to the programmable logic controllers that control the modulators and transmitters and monitor the readbacks until conditions permit moving to the next step in the process. A set of screens allows watching the states of the systems and the commands in progress, either on an overall screen with all of the systems at once (see Fig. 1), or on detailed screens for each system (see Fig. 2).

The detail screens display the states of all of the relevant parameters and the last message in the log that records the start-up process. The oval around the current state in the sequence is highlighted in hot pink to show the status of the process. The screens also offer control of relevant parameters, such as settings to be sent to the equipment during the course of the start up.

Using the start-up sequences, operators are able to turn on the power to all of the systems in about five minutes, and shut them all off in about one minute, even including delays to smooth out power consumption changes.

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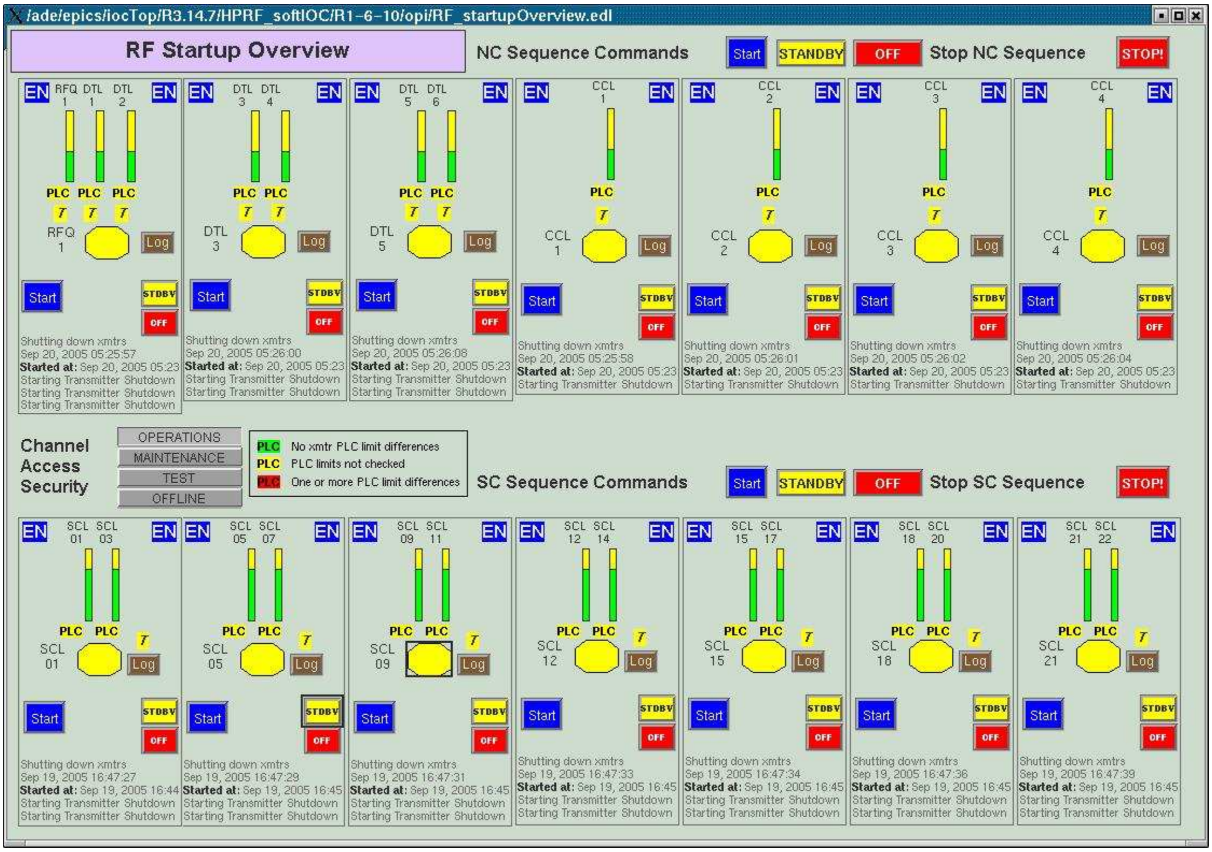

Figure 1: The RF Start-up Overview Screen shows the status of the HPRF systems and the start-up Sequences.

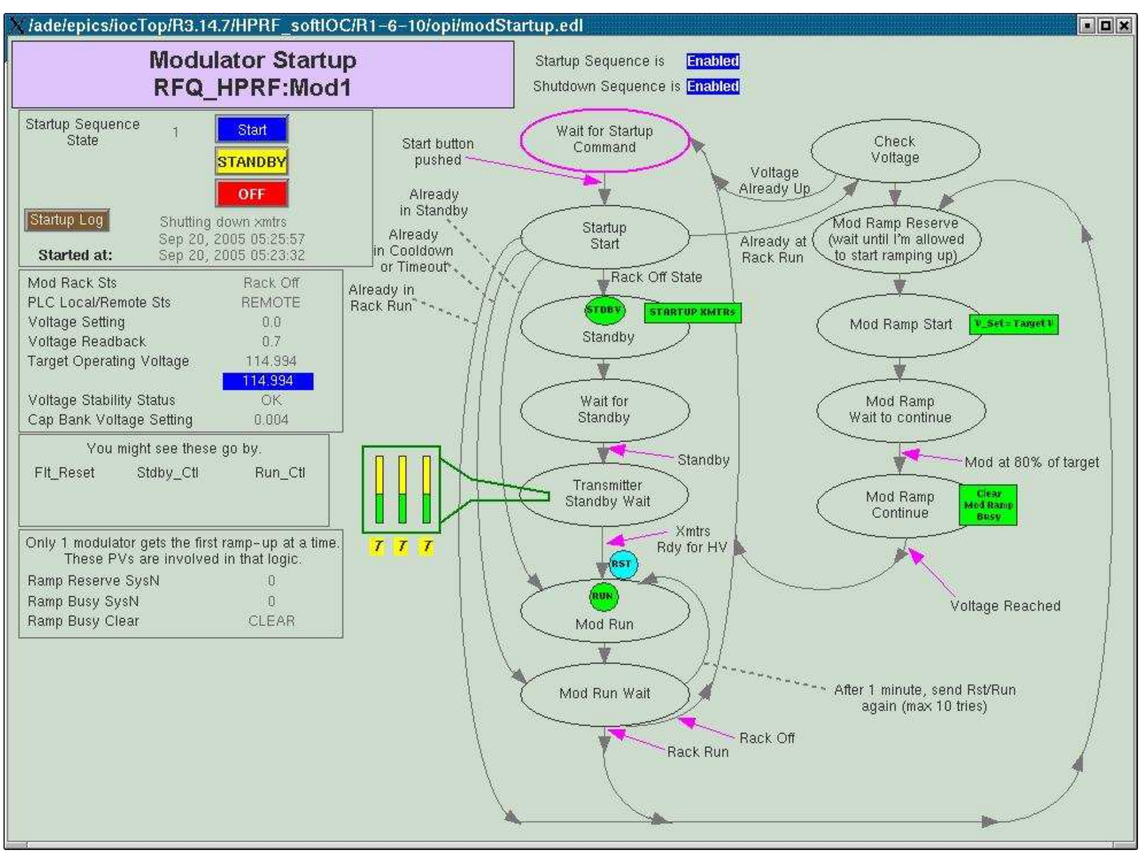

Figure 2: The Modulator Start-up Screen gives details of the modulator start-up sequence and allows access to the operating voltage to be sent to the modulator during the sequence.

Planned Improvements

After the capability to change the constants and limits involved in transmitter and klystron control is added to the EPICS control system, the constants and limits will be checked as part of the start-up procedure, and values corrected or operators alerted as necessary. To prolong the lifetime of the klystrons the filaments will be set to 25% of nominal value if the high voltage is off for longer than one hour. The warm-up time will be based on the filament resistance rather than a fixed time. The filament resistance increases as it gets hotter. We measure filament current and voltage so determining when a set resistance is exceeded is a straight-forward calculation.
At present, operator intervention is required to start the low level RF systems using separate sequences. Possibly, after more experience starting up the systems, the start-up sequences will be merged with each other.

CRYOGENIC SEQUENCES

The 81 superconducting radio frequency cavities comprising the cold section of the Linac are cooled to 2.1K by a 2400 Watt cryogenic refrigeration system [4]. Like those in the high power RF system, sequences to perform backfill and start-up of the 2.1K cold box as well as to handle trips of the 2.1K cold box have been developed and deployed. The SNS project has been fortunate in having the help of experts from Thomas Jefferson Laboratory to help set up all of these sequences, so that the knowledge of the experts is captured within the cryogenic control system.
EPICS screens allow control and display of the processes as well as information about what each process is doing at each stage (see Figs. 3, 4 and 5).

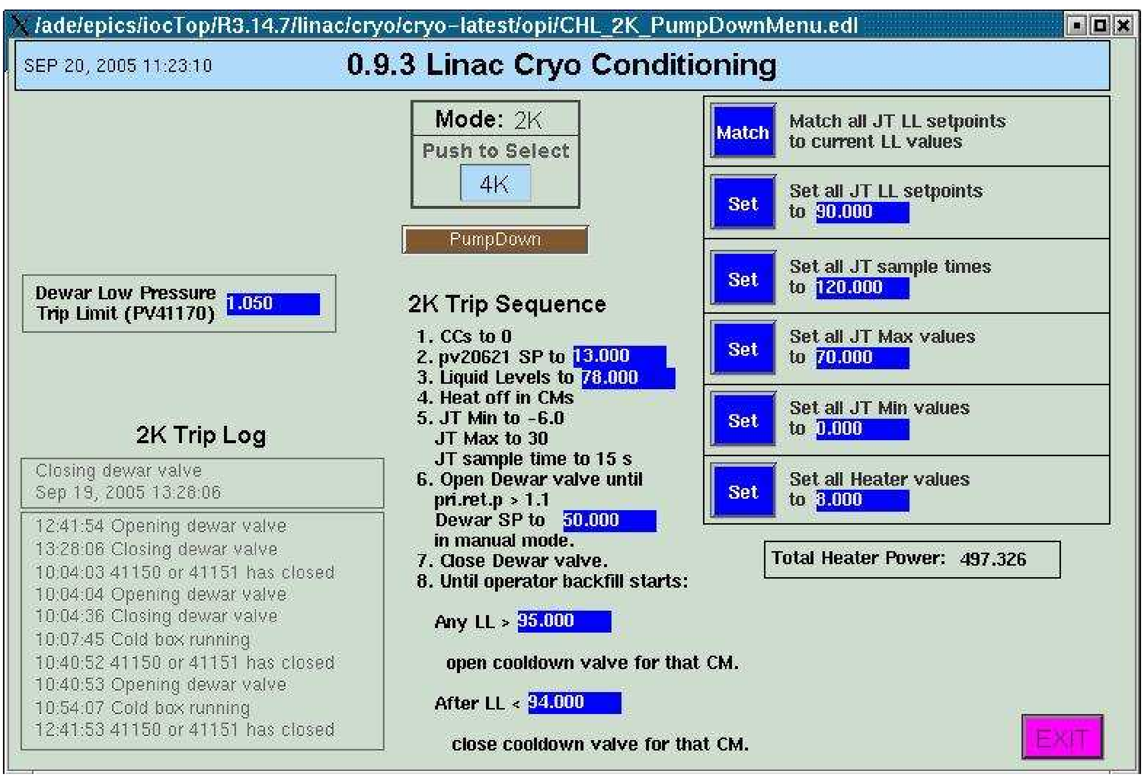

Figure 2: The Cryogenic Conditioning Screen allows access to the 2K trip log, control of the trip parameters as well as access to the pump down and backfill screens.

Planned Improvements

Similar sequences and access screens perform automatic valve control and energy management in the cryogenic system. At present the energy management system uses a single bit ("On" = 1 Watt) for the RF power dissipated into each cavity. In the future, a more accurate power calculation will be provided

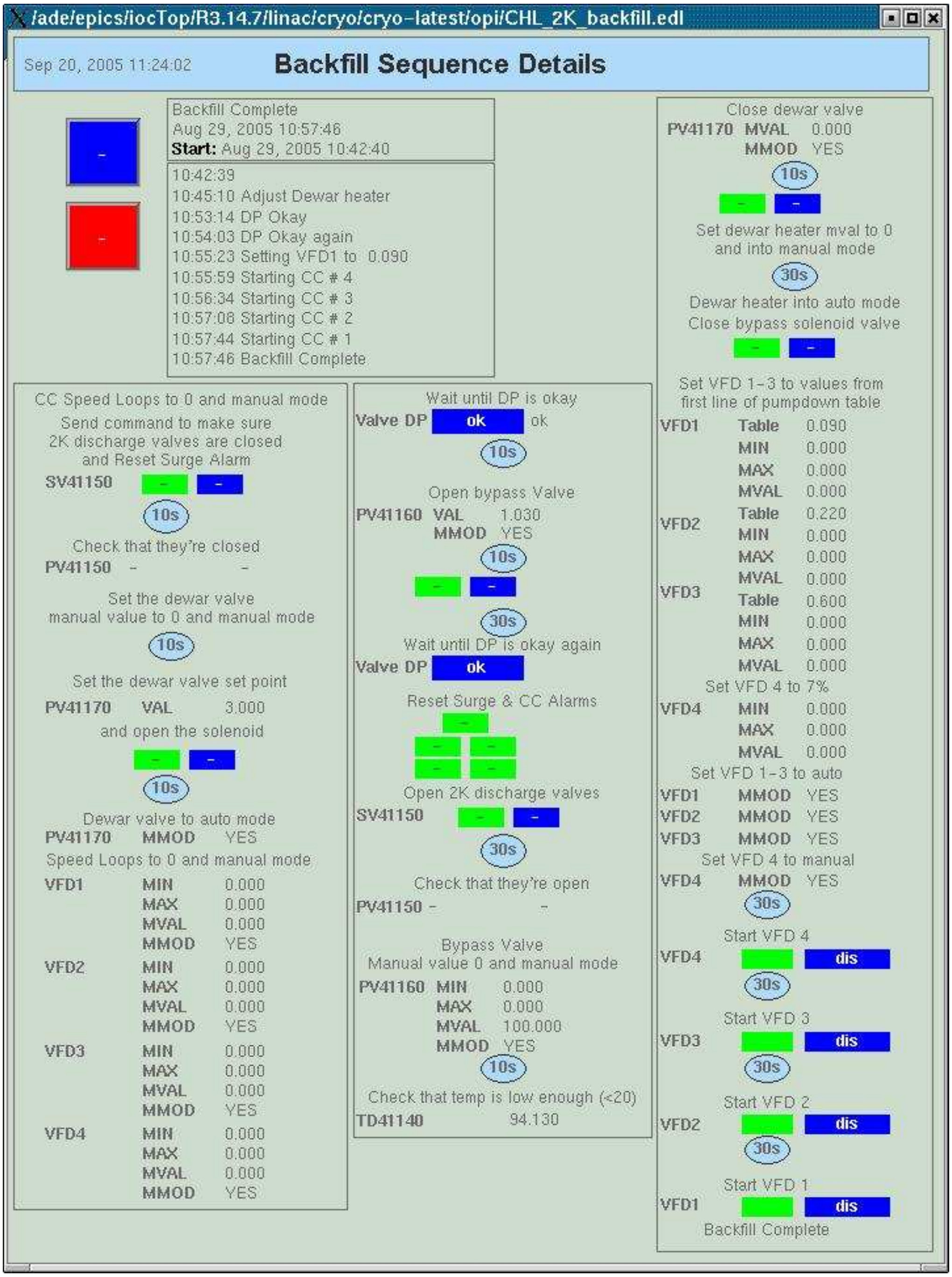

Figure 3: The Backfill Screen allows the backfill sequence to be started, displays the sequence log, and shows what the backfill sequence does at each step. It gives the status of all the parameters changed in the sequence. The steps in the current state in the sequence are highlighted by a hot pink rectangle to show the status of the process.

Figure 4: The Cold Compressor Pump down Screen shows the values to be sent to the control loops at each stage of the pump down process.

SOFT IOCS

All of the sequences described herein were developed on Linux "soft" input-output controllers (IOCs), which act like ordinary IOCs except that they share a Linux server rather than running on their own embedded processors [5]. Soft IOCs can be reinitialized ("rebooted") within a few seconds without affecting the traditional IOC that controls and monitors all of the equipment.

All of these sequences are started or stopped via process variables which are defined in EPICS databases in the soft IOCs and which communicate via EPICS channel access. Similarly, all of the monitoring and control is performed via EPICS channel access.

CONCLUSIONS

Automatic sequences have eased the tasks of starting up the high power RF and cryogenic systems at the Spallation Neutron Source, capturing the knowledge of experts in consistent procedures. Soft IOCs have afforded a flexible way to coordinate the control of devices that are accessed via a number of traditional IOCs.

REFERENCES

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