

THE EPICS BASED CONTROL SYSTEM AT THE FREIA LABORATORY*

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Abstract

FREIA (Facility for REsearch and Instrumentation for Accelerator development) Laboratory at Uppsala University, Sweden, is a new facility, inaugurated 2013. Initially FREIA is testing and developing superconducting accelerating cavities and high power RF sources in collaboration with the European Spallation Source (ESS). Later projects include testing of superconducting cavities and magnets for the high luminosity LHC. The high level control, alarm system and archiving is implemented in EPICS. Presently this includes a helium liquefaction plant, a horizontal test cryostat, two high power RF amplifiers, a low level RF system, environment monitoring and safety systems. Some attention will be given to integration of commercially acquired systems as well as the safety system, interlocks and radiation monitoring. The implementation of the EPICS environment follows closely that of ESS and thus can provide a test bench for developments at ESS.

INTRODUCTION

The FREIA laboratory [1] at Uppsala University is established in order to support the development of accelerator technology and instrumentation. The major commitment from the start is testing the 26 superconducting double-spoke cavities arranged, in pairs, in 13 cryo modules that will make up part of the European Spallation Source (ESS) linac. [2] The 5 MW, 2 GeV proton linac is scheduled to deliver the first beam on target in 2019 and reach full power during the following years. FREIA has also taken on the test and evaluation of the high power RF systems necessary to feed the cavities. Since the start in 2013, FREIA has installed the extensive infrastructure necessary for the tests. This includes a high capacity (140 l/h) helium liquefaction plant and a tailor-made horizontal cryostat, which can serve two superconducting cavities simultaneously. The high-power tests require feeding the cavities with 3.5 ms long 352 MHz RF pulses of 400 kW power. It also includes cooling the cavities to, and keeping them at, 2 K. The tests take place in a concrete bunker for radiation protection. There are a number of subsystems in the FREIA Laboratory that need to be controlled or supervised. Most of them have a local control system supplied by the vendor of the equipment but nevertheless there are several advantages in having a common control system.

- A uniform operator interface to all equipment.
- Common services like data logging, alarm manager, electronic logbooks.
- Remote access

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THE FREIA CONTROL SYSTEM

The high level control system used at FREIA is based on EPICS (Experimental Physics and Industrial Control System) [3]. EPICS is a set of Open Source software tools, libraries and applications developed collaboratively and used worldwide to create distributed soft real-time control systems for scientific instruments such as a particle accelerators, telescopes and other large scientific experiments. This is also the high level control system adopted by ESS. Thus, equipment like the Low Level RF (LLRF) prototype system [4] can easily be tested and evaluated at FREIA and ESS can directly benefit from experience at FREIA. Conversely, FREIA can benefit from software developments at ESS by using the ESS EPICS Environment (EEE).

EPICS Use

On top of EPICS there are a number of useful utilities that have been implemented at FREIA. The Control System Studio (CSS) [5,6] is used to design and show operator interfaces. CSS can also be used to plot archived data, show and configure alarms. The data archiving system BEAUTY (Best Ever Archive Toolset Yet) [6] uses a relational database system (RDB) to store the so called process variables that contain all the volatile information in the EPICS control system. Different RDB's are possible but in FREIA POSTGRES [7] is used. In addition to this the newer, faster, EPICS archiver, Archive Appliance [8], has been implemented in parallel to BEAUTY.



Figure 1: Example of an Archive Appliance plot.

A system for handling alarms called BEAST (Best Ever Alarm System Toolkit) [6] is also used. BEAST like BEAUTY uses POSTGRES at FREIA, to store configuration and history. Raised alarms can be sent by email or sms to responsible persons.

Computer System

The computer hardware used to run EPICS at FREIA consists mainly of an HP ProLiant DL380p Gen8 – Server [9] with 128 Gb of memory, 200 MB SSD, 300 Gb Raid1 and one Tb Raid1 running Ubuntu. On this several virtual machines running Scientific Linux or Centos provide the different EPICS services. Several NUC’s (i3, 4 Gb ram) [10] are used to run the Input Output Controllers (IOC’s). These are the programs that are used by EPICS to communicate with the hardware and handle all the process variables in the system. In addition EPICS is running in a number of office computers and on board computers like in the ESS LLRF system. A few Raspberry Pies are also used to measure special parameters in the He accounting and recovery system [11].

The computers and virtual machines that are important for the operation of the control system are continuously monitored by EPICS using SNMP (Simple Network Management Protocol).

The computers and other networked devices are organized in a private network (NAT) with several subnets. An EPICS gateway connects the private network to the office computers.

Local and Low Level systems

There is a diversity of hardware used in the different subsystems in FREIA, equipped with autonomous local controllers. This can be vendor specific solutions or general purpose PLCs (Programmable Logic controllers) and high performance FPGA systems.

Table 1: Subsystems Controlled from EPICS

System	Local/Low level
Linde helium liquefaction facility	S7-315 PLC
Horizontal cryostat (HNOSS)	S7-317 PLC
High power RF amplifiers:	
DB Elettronica	S7-1200 PLC
Itelco Electrosys	Micro controller
Sub-atmospheric He pumps	S7-300 PLC
Radiation monitoring system	DPU, PC
Oxygen deficiency monitors	Modbus, S7-PLC
Bunker clearing/interlock	S7-314C PLC
Low Level RF (LLRF) system	FPGA
Fast interlocks	NI cRIO-9024
Slow interlocks	S7-314C PLC
Deionized water cooling system	S7-314C PLC
Vacuum system	Serial interface
Computer and Network monitoring	SNMP

We have two LLRF control systems:

1) A μ TCA.4 [4] based system developed at Lund University that is a first prototype for the ESS’s LLRF control system. This is built around FPGA boards and comes with an extensive EPICS user interface.

2) A National Instrument PXIe based system [12] developed at FREIA, with a user interface and measurement control, programmed in LabView, that acts also as a fast

data acquisition system (10 channels, 250 Ms/s, input bandwidth 800 Mhz). The LabView [13] program gets data from external equipment via EPICS and can also provide output via EPICS.

For high power RF tests FREIA has two different tetrode RF amplifiers, 352 MHz, 400 kW, 14 Hz pulsed. One is locally steered by a microcontroller and interfaced to EPICS via Ethernet using the SNMP protocol. The other uses a local PLC system.

The liquid helium plant and the horizontal cryostat are locally controlled by PLC systems supplied by the vendor. They are interfaced to EPICS and the controls are replicated using CSS operator interfaces.

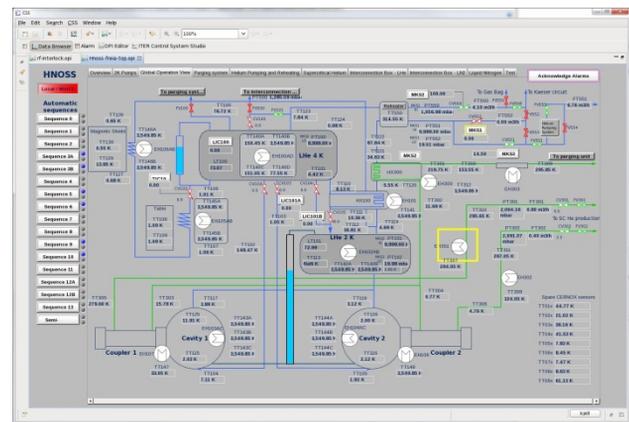


Figure 2: The top operator interface for the horizontal cryostat.

Machine Protection and Safety Systems

The machine protection system consists of a fast interlock system that controls the RF switches cutting off the input signal to the RF stations. It is built on the NI cRIO-9024 platform [14]. In its current configuration it supports 16 fast digital inputs (150 ns response time), 16 slower (response within 10 – 20 μ s) and 16 analogue channels (100 kHz) with programmable thresholds.

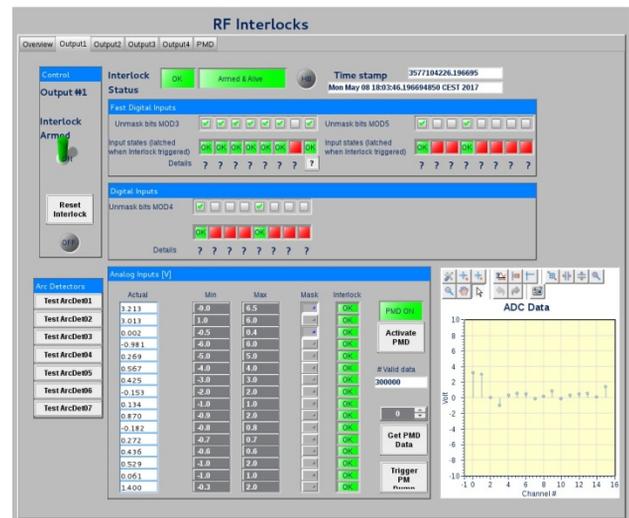


Figure 3: CSS operator interface for setting up the RF interlocks.

Up to 300000 data points in each analogue channel are written to the circular buffer for post mortem analysis.

In addition there is a slow interlock system based on a Siemens S7-300 PLC system. The current system support about 100 i/o channels but there is still room for expansion of the system if needed

For personal safety there is a set of radiation area monitors from the ROTEM MEDISMARTS system. [15] They are read by a set of data processing units (DPU's), one for each detector. The DPU's also display the current dose rate. The data is collected via a serial bus by a PC which broadcast the readout over Ethernet to be easily picked up by the EPICS stream device driver. The radiation protection bunker is protected by a door interlock. A clearing procedure is required before closing the door and enabling RF. This is implemented in the slow interlock PLC.



Figure 4: Bunker door showing clearing indicator lamp and the switch to trigger the PLC interlock and the hardware interlock of the RF stations. Just behind the closed door you can.

There are oxygen deficiency monitors installed in the bunker and compressor room and an RF monitoring system is being developed at FREIA.



Figure 5: EPICS status display for the FREIA bunker showing the radiation monitors with graphs of dose rate, warnings messages- and clearing status.

CONCLUSION

FREIA has implemented a control system that integrates all the different subsystems necessary for a cryogenic high power RF lab. The use of EPICS simplifies the exchange of experience and equipment with ESS. EPICS is a highly scalable system which can handle new equip-

ment that will be constantly arriving at FREIA during the coming years.

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