INTEGRATION OF SAMPLE ENVIRONMENT SYSTEMS AT ESS

A. Pettersson, T. Bryś, D. Brodrick, M. Hartl, European Spallation Source ERIC, Lund, Sweden

Abstract

Sample Environment Systems (SES) are used to control the environment of a sample. At ESS all SES will be integrated into the control system to enable recording of data and allow user control. In this paper a specific SES is introduced and the ingoing hardware components are described. An overview of the control structure of the system is given which is followed by a walkthrough of the systems and tools used in the integration. How signal naming have been approach is touched and the use of the software tools developed at ESS is explained. The status of the current setup is presented and finally the plans for the continued work on the system is detailed.

INTRODUCTION

ESS will be one of the brightest neutron sources built. To be able to utilise the full capacity of the ESS source all systems must be as reliable, easy to setup and as maintainable as possible to minimize experiment changeover times. For most experiments SES will be used to control e.g. the temperature, magnetic field, pressure, humidity, etc. of the sample measured. Consequently the SES will usually be changed between experiments or even during the same experiment. Due to the multitude of different SES systems and frequent usage at different instruments it is very important to have a robust control system.

This paper presents the current approach taken at ESS for the SES integration and control.

The particular setup described in this paper consists of a top-loading Closed Cycle Refrigerator (CCR) optimized for neutron scattering experiments between 10K and 300K. It was designed as a small, transportable CCR that can be used for transmission measurements on various neutron scattering instruments to determine neutron scattering cross sections of materials for developing scattering kernels. In addition to these features, the CCR also has sapphire windows at the sample height to allow transmission of optical light for performing spectroscopy. In our current application, the CCR is used to analyze the ortho- and parahydrogen fraction in liquid hydrogen using Raman spectroscopy. This is a test stand for the future online monitoring of ortho-/parahydrogen fraction in the ESS hydrogen moderators.

THE SAMPLE ENVIRONMENT SYSTEM

At ESS a SES is defined as the Sample Environment Equipment (SEE), which contains the sample and will be placed in the beam, and the Auxiliary Equipment (AE) which are the components the SEE need to run such as compressors, temperature controllers, logic controllers etc.

With this definition the CCR described above is the SEE, see Fig. 1. This will hold the sample and be placed in the beam during measurement. This particular SES also includes AE components. Connected to a Helium compressor, the CCR will provide cooling power to cool down the sample. To minimize heat transfer from the environment to the sample it is placed inside a vacuum housing, which is evacuated using the vacuum pumps, listed in Table 1. Control of the temperature is done using a temperature controller. The temperature controller measures the temperature of the sample and runs an internal PID control loop. The output from the PID loop is used to regulate a heater mounted inside the CCR enabling control of the sample temperature. A vacuum gauge is connected to the CCR to be able to verify that required vacuum for operation is reached. In this setup also a spectrometer is included consisting of a laser unit and a spectrometer for light spectroscopy as described in the introduction. In order to control these devices as a SES an industrial PC is mounted with the equipment, running the controls as explained in following sections. A schematic overview of the SES is shown in Fig. 2.
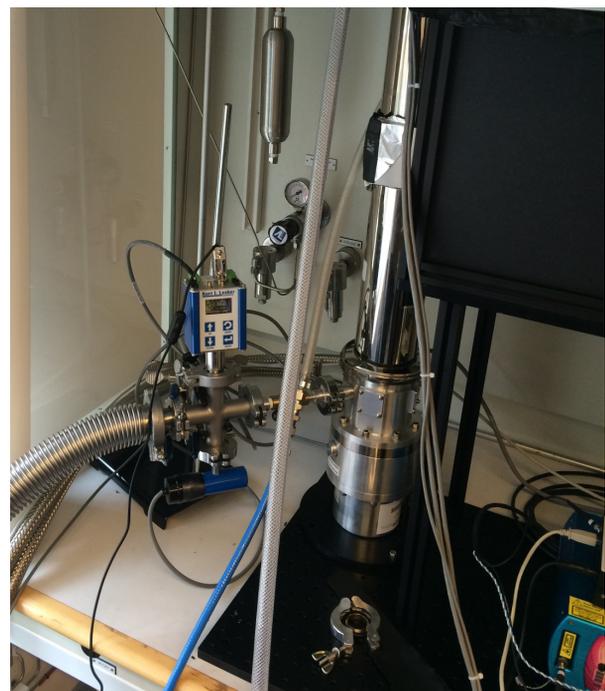

Figure. 1: Photo of the SES. The tube shaped object in the middle is the CCR. In the lower right corner the laser power unit is visible. In the upper right quarter the laser probe safety enclosure is seen. To the left the vacuum

gauge is visible. Additional auxiliary equipment is outside picture.

Table 1: SES Setup Hardware.

| Equipment	Brand/Model	Communication
SEE: CCR	JANIS	N/A
AE: Vacuum gauge	LESKER	RS485 serial->MOXA
AE: Serial server	MOXA	TCP/IP-RS485
AE: Temperature controller	LakeShore336	TCP/IP
AE: Helium Compressor	ZEPHYR/HC-4A	Via LakeShore relay
AE: Industrial PC	Fitlet	TCP/IP
AE: Switch		
AE: Laser	Ocean Optics	manual ON/OFF
AE: Rough vacuum pump	Edwards	manual ON/OFF
AE: Turbo vacuum pump	Pfeiffer/hiCUBE	N/A, manual ON/OFF
AE: Spectrometer	OceanOptics/QEPro	USB/proprietary driver
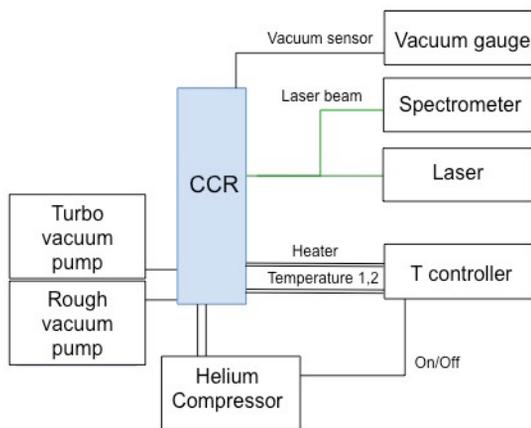
Figure. 2: A schematic overview of the complete SES.

CONTROL SYSTEM

Control Overview

As described above the control of the temperature is handled by the temperature controller. In this particular implementation a relay on the temperature controller is furthermore used to stop and start the Helium compressor. In practice a cool down cycle is thus started by requesting the compressor to be started via the temperature controller. The CCR will start to provide cooling and the PID control loop will regulate the temperature to the setpoint. The vacuum gauge and the spectrometer are not used to control the SES but will provide monitoring of the system status and the sample.

TUPHA141

The industrial PC is used as the control hub of the complete SES. It will run the control software that provides connection to the overall ESS control system and communicates with the SEE and AE, see Fig. 3.
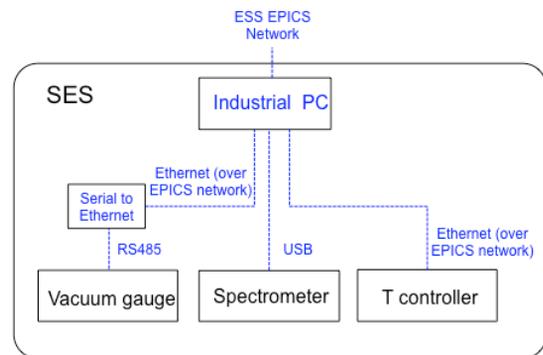

Figure. 3: View of the control system structure. The figure only show the directly controlled hardware. The industrial PC runs the required EPICS control software to communicate with the SEE and AE in the SES.

EPICS Development at ESS.

The Experimental Physics and Industrial Control Systems – EPICS [1] is the signal backbone at ESS. All SES will need to be integrated and connected to the ESS EPICS network to enable control and storage of sample environment data. EPICS Input/Output Controllers (IOC), the interface between the SES device and the EPICS network, are developed on the ESS EPICS Environment (EEE) machines. These machines run the ESS IOCs and assure an aligned development process, simplifying development and troubleshooting. The development machines are setup with the official ESS EPICS version, module libraries and essential development tools such as Control Systems Studio (CSS) etc.

System Configuration and Naming

Due to the size of the ESS facility it is essential to keep a structured approach to signal naming and to keep track of system configurations. To enable this ESS have developed a naming convention and a naming database. The naming convention follows the pattern:

 Sec-Sub:Dis-Dev-Idx:Property.FIELD
Where:

- Sec-Sub is the location in the facility
- Dis-Dev-Idx is branch of knowledge and device
- Property is observable property of device
- FIELD the parameter. eg. A field of a particular EPICS Process Variable (PV)

This system have been used for the individual SEE integrated in the project but is yet to be setup for the complete SES. One of the challenges for the SES integration is that it then need to reflect the mobility of the system as well as being informative on the hierarchical structure and reflect the SES as a unit.

The Controls Configuration DataBase (CCDB), developed at ESS, allows modelling a specific SES comprising hardware, IOC's and naming. Via the CCDB and an associated utility IOC Factory it becomes known to the system what EPICS IOCs to run for what industrial PC.

In the SES described here is defined a Lab containing a SES with multiple slots for the devices in Table 1. The Industrial PC slot is in turn defined to have 4 slots available for IOCs. Each IOC is the defined to control the appropriate device in the overall SES setup.

Development System and Repositories

All EPICS development at ESS is done according to defined workflows. Within ESS version handling is used and all official repositories are maintained on Bitbucket. Tagging commits with release versions triggers an automated build and setup of the module on the NFS server. This helps ensure accessing the correct IOC for all SEE running it. It also allows rollback to earlier releases.

In the SES presented here multiple developers have worked on development of the IOCs making it essential to have version handling and easy access to the source code.

Automated IOC Deployment and Network Boot

The previously described systems allow providing automatic deployment of EPICS IOCs as a industrial PC for SES control is connected. The IOC Factory tool developed at ESS will work with these systems and will ensure that the correct IOC is loaded. It allows easy selection of the latest version, rollback to earlier versions, fast deployments of hundreds similar IOC's e.g. for the accelerator systems, and also to easily change some system parameters.

To reduce the risk of incompatible IOCs being used for identical devices, diskless industrial PCs will be used. These machines will network boot on start-up and via the IOC factory start the correct IOC for its connected devices. This will reduce the risk of machines running old software and also simplify maintenance greatly.

SES might not always be the best suited setups for this proposed approach. Some systems will require local control for safety issues etc. but this will be addressed on a case to case basis.

EPICS Integration

At ESS work has been ongoing to develop IOCs for the vacuum gauge, spectrometer, temperature controller and compressor. The temperature controller is based on the development at the Diamond Light Source but was modified and extended to fit ESS needs. The vacuum gauge had an EPICS IOC driver available from the manufacturer. To run the spectrometer a manufacturer proprietary library had to be built in to the solution. As the vacuum gauge only communicated via RS485 a serial terminal was used to bridge over to Ethernet to simplify connections to EPICS in a reliable way.

In the current controls model for SE Systems of ESS it is decided to use a local industrial PC mounted with the SES. This PC will act as the central control for the SES system and will run the EPICS software required. With this approach a required "plug and play" functionality of the SES systems is easier to achieve and also it can be used to support EtherCAT modules when external hardware need to be controlled, e.g valve control or sensor readout.

For each device a Graphical User Interface have been developed in Control Systems Studio (CSS). CSS allow drag and drop style development of GUI's with buttons, text boxes, meters etc. Each widget can be connected to the IOC PV's. Fig. 4 show an example of one of the CSS GUIs. These interfaces will mainly be use as an engineering interface and will thus contain a full set of commands. Scientific users will use another interface explained in the following sections.

For the spectrometer the first GUI was developed to be similar to the proprietary GUI available from the vendor to maintain familiarity. The spectrometer data readout array was handled in EPICS using the waveform records.
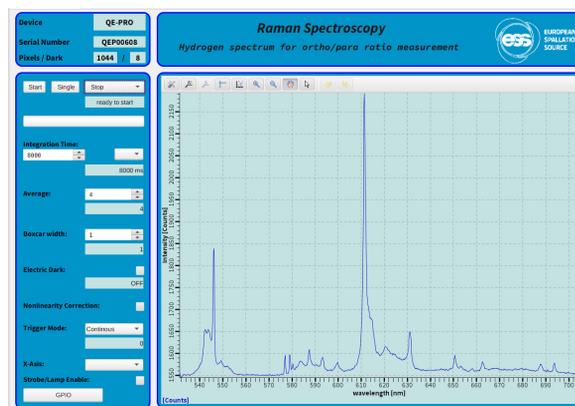

Figure. 4 Example of a CS Studio GUI engineering screen from the project showing the Spectrometer GUI.

An EPICS archive has also been setup for testing and evaluation during these early integrations. The current archiver is the Archiver Appliance. It is run on the lab network set up for Sample Environment, and other groups, controls development. The archiver allows a straightforward approach to store and retrieve data from SES. Signals form the integration process are enlisted in the archive and made accessible through a web application.

The CCR setup has been fully integrated into EPICS and GUIs have been developed. The vacuum gauge, spectrometer and the Lakeshore all have individual GUIs to keep it modular. A summary screen for the entire Sample Environment System will be developed, to enable an overview, later in the project. As a relay on the temperature controller is used to switch the compressor on and off this is controlled from the temperature controller GUI.

TUPHA141

Experiment Control System (ECS) Integration

In 2017 a decision was taken at ESS to use the NICOS 2 as the Experiment Control System. NICOS 2 is a Python based control system originating from FRM-II. This system will be the interface towards the scientific users. NICOS 2 will act upon the signals available on the EPICS network from the EPICS integration. NICOS 2 allow plotting of data, scripting of sequences and to setup scans etc. These are functions required to perform an experiment where for example a temperature stepwise is changed and measurements taken at the steps when the temperature is stabilized.

COMISSIONING IN ESS WORKSHOPS

An EPICS control network has been setup in the current temporary ESS workshops, accessible over VPN also form office facilities. In the Integrated Controls Division main lab servers are running the IOC Factory, CCDB, network booting, archiver service etc. The CCR SES resides in a lab in another building, where the SES hardware and the industrial PC are connected to the network via a small switch. As the PC network boots it will also start-up the appropriate IOC's defined in the CCDB. Subscribed signals will be stored in the Archiver. A CSS GUI can be started on any machine in the office or in other workshops to remotely monitor signals and control the equipment.

OUTLOOK

A discovery system is being developed where the EPICS Channel Finder will be used to detect running IOC's. As an IOC is started up this will be flagged in the Channel Finder and NICOS 2 will be notified, prompting a dialogue to the user to ask if this SES is to be used. A summary GUI view of the system will also be setup in both CSS and NICOS 2.

It will be further explored on how such setup can be handled in a modular way where the e.g. spectrometer can be exchanged for something else in a straightforward way.

The complete setup will be built into a mobile rack for use on multiple beamlines.

Last but not least the setup and the tools used will be tested to verify that this is a suitable approach to run SES at a large neutron scattering facility.

REFERENCES

[1] EPICS, http://www.aps.anl.gov/epics/