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CRYOGENICS MONITORING AND CONTROL SYSTEM FOR EMBL FACILITIES AT PETRA III

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Abstract

At the integrated facility for structural biology of the EMBL at PETRA III on the DESY campus in Hamburg, several devices require cryogenic cooling with liquid nitrogen (LN2). For the cryogenic devices local servers and clients have been created to monitor and operate the corresponding sensors, actuators and provide the safety logic. In addition, the local cryo-clients are integrated in a cryogenics supervision interface. The supervision client allows password protected access to three levels: monitoring, operator and expert. The monitoring level offers an overview of the status of all EMBL cryogenic sub-systems. At the higher access levels, cryogenic components can be also controlled. The application can be used from remote via a VPN connection or the TeamViewer software or a web client (in preparation). Because of the heterogeneity of the cryogenic devices different protocols for interfacing had to be applied.

INTRODUCTION

Cryogenic installations and their controls are key components of the infrastructure for many large research facilities [1-3]. This is also valid for smaller size structural biology facilities like the EMBL beamlines at PETRA III on the DESY campus in Hamburg where EMBL is operating a small angle scattering beamline for proteins in solution and two macromolecular crystallography beamlines. Cryogenic cooling with liquid nitrogen (LN2) is needed for commercial or in-house built instruments like cryo-coolers to stabilize the temperature of the Double Crystal Monochromators (DCMs) under thermal load, cold gas stream units for cryo-protection of protein crystals during the different phases of an experiment and cryogenic sample dewars for robotic sample handling under LN2. In order to communicate with the controllers of each device, servers and clients based on the TINE control system (Three-fold Integrated Networking Environment) developed by DESY [4] and the LabVIEW software suite [5] have been created, that monitor and operate the corresponding sensors, actuators and provide the safety logic. Depending on the options offered by the different controllers, the servers had to be interfaced with several other communication protocols such as EtherCAT [6], ADS-OCX [7] and EPICS [8]. The wide variety of instruments that have to be monitored and controlled, with single clients for each element, distributed over several computers on different beamlines, called for centralizing the cryogenic information. For every beamline and/or laboratory, a central client has been written and an overarching cryo-client in which all cryogenic devices are combined that are operated at the EMBL PETRA III facilities.

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MATERIAL AND METHODS

Hardware Components

LN2 is supplied by central storage tanks managed by DESY to all consumers in the Max-von-Laue Hall where also the EMBL beamlines are situated. The EMBL installations comprise (see Fig. 1):

- three cryo-coolers for the DCMs (from FMB Oxford) [9] of the P12, P13 (type D cryo-coolers) and P14 beamlines (type XV cryo-cooler);
- four cold gas stream units for cryo-crystallography, ('cryostream 800' series by Oxford Cryosystems [10]);
- three LN2 sample storage dewars for robotic protein crystal mounting, the in-house built MARVIN systems [11] at the P13 and P14 beamlines respectively and for the automatic Crystal Direct Harvester (CDH) system [12].

Hardware:

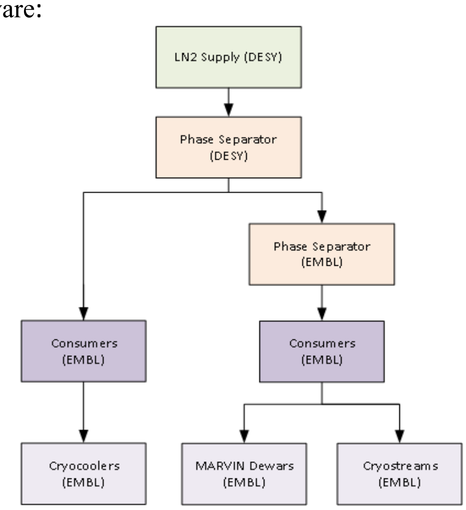

Figure 1: Cryogenics system: layered structure of hardware.

An additional 100 liter (Cryotherm [13]) phase separator has been installed on top of the macromolecular crystallography beamlines in sector-9 of the Max-von-Laue hall in order to achieve an efficient filling of the different LN2 reservoirs (with exception of the ones for the DCM cryo-coolers).

The LN2 consumers are connected by super insulated LN2 transfer lines equipped with remotely controllable

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valves. Signals from valves, from several different LN2 level sensor systems, temperature sensors, pressure gauges and from oxygen content monitors are fed into PLCs respectively PCs depending on the device.

PLC/PC Software and Interfaces

Due to the variety of systems by different suppliers, the data has to be read out using different protocols and technology. The general structure of the controls of the cryogenic system is depicted in Fig. 2.

a) The control server for the central LN2 supply under DESY responsibility, is based on EPICS (Experimental Physics and Industrial Control Systems) and is a read-only server for EMBL. This is achieved by using a gateway from where the relevant values can be transferred with the standard EPICS commands for ‘Channel Access’. On the EMBL side, the data is distributed through TINE. For this, a TINE server has been created in order to handle the signals from the central LN2 tanks, the main phase separator, the sector-9 phase separator and its valves and pressure gauges. All signals are available in the entirely separate EMBL network.

The workflow of the server comprises only a few steps:

1. Initialization upon start of the program (in case of an error during initialization, the subsequent commands will not be executed).
2. Requesting data from DESY server using the EPICS command ‘caget’.
3. Parsing of the string returned by the DESY server and pushing it to the TINE server.
4. Repetition of steps 2 and 3 to read more data.

b) The cryo-cooler at the P14 beamline was the first upgraded to the FMB Oxford XV type, equipped with a controller using EPICS. Therefore, a new program has been written using LabVIEW. This piece of software is at the same time an EPICS client and a TINE server. Its main function is to read out the data from the EPICS server and push it into the TINE server.

For the older type D cryo-coolers installed at the P12 and P13 beamlines, the standard TINE installation could not be used because of superseded hard- and software. Therefore, the readout has been achieved using an ADS-OCX API running on a BC9100 bus controller module by Beckhoff. Readouts have to be converted afterwards on the server side by a LabVIEW-TINE server. Depending on the nature of the signals (current, voltage, frequency etc.) different conversions of the raw data have to be applied before making them available on the entire network.

c) The cryostream 800 controller uses a firmware called *cryoconnector*. Once the controller is connected to a computer through USB, the software creates three XML files (Connection.xml, Commands.xml, Status.xml) containing the ID of the device, status variables and commands for execution.

The XML files are accessed using LabVIEW for reading out the information or sending a command. Four LabVIEW routines verify the connection and data path, read or send information (ReadConnections.vi, ReadStatus.vi, ReadInfo.vi and SetTemp.vi).

Software:

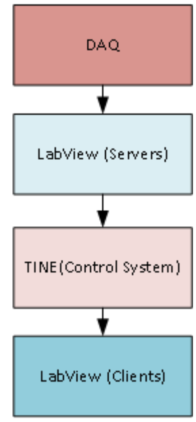

Figure 2: Cryogenics system: layered structure of software.

d) Most of the instruments at the EMBL PETRA III beamlines are controlled by Beckhoff PLCs [13]. In this manner are handled also:

- the automatic filling/refilling with LN2 of the MARVIN sample changer dewars,
- the monitoring and control of valves in the LN2 transfer lines of the EMBL LN2-subnet,
- the cryogenic gas streams at the beamlines and the CDH,
- different LN2 level sensors systems with analog and digital outputs [14, 15],
- personnel and instrument safety logic related to LN2 usage.

A server based on the powerful Common Device Interface (CDI) offered by TINE can be created by simply preparing a configuration file. It allows linking the variables in the PLC with the properties of the TINE server pushing the data to the server as soon as the values change in the PLC. As this type of server has no graphical user interface (GUI), but instead uses a prompt window of the operating system only, it calls for a generic client (see next paragraph).

Software Clients

Depending on the purpose and on the target group, three types of clients have been developed to monitor and control the cryogenic devices.

Initially, individual clients have been provided to configure and control single devices on an expert level.

Another type of client has been created in order to provide to a beamline operator an overview of all devices in one of the beamlines or in the laboratory at one glance (for an example see Fig. 3).

A third interface called ‘Cryogenic Supervision System’ gives access to all information shown in the clients described above, i.e. all cryogenic installations of EMBL at PETRA III to a cryogenic expert (see Fig. 4). This client can be accessed remotely using VPN connection, TeamViewer software [16] or a web client. This increases the versatility of the system, especially in situations when errors occur and the expert in charge is not on site, such as

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on weekends, holidays or because of access restrictions due to pandemics.

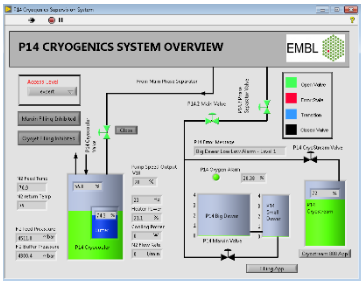

Figure 3: P14 specific cryogenics GUI.

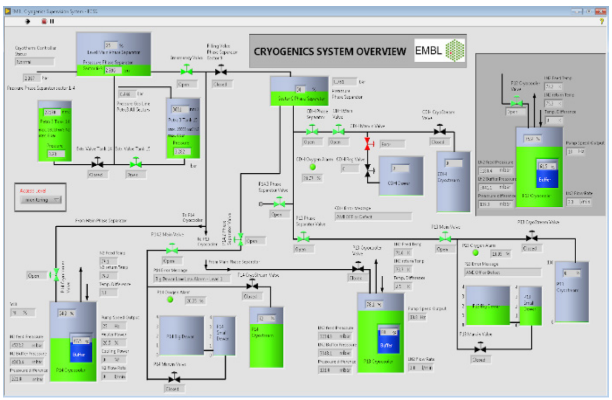

Figure 4: EMBL Cryogenic Supervision System.

This graphical user interface is password protected and by default the access level is set to monitoring. The monitoring mode allows to display the data of all devices needed for standard operation like status of valves, cryostream temperature and LN2 levels in reservoirs, but not to set values.

In the operator access level it is possible to modify some parameters like manually inhibiting automatic dewar refills or modifying the temperature of the cold gas of the cryostream devices. However, only parameters that are not relevant for the instrument safety can be set.

The expert mode gives access also to the lower level applications which allows to set all parameters including critical ones like the opening and closing of valves (see Fig. 5).

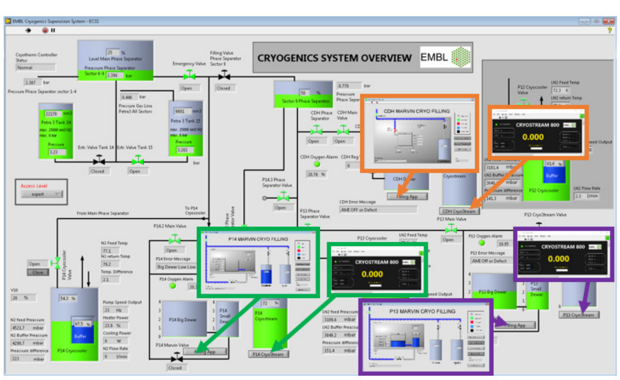

Figure 5: Cryogenics supervision system with access to sub-systems.

In the GUI, some features are changing according to the status or value of parameters e.g.,

- Colors indicate the status of valves.
- LN2 filling levels are indicated graphically and numerically.
- Some buttons and prompts are hidden as a function of the access level.
- Warnings and error messages are displayed in designated fields.

DISCUSSIONS AND OUTLOOK

The system has been deployed and is in full operation. Having a unique client that comprises all the cryogenics elements gives the expert user a complete notion of the status of the entire system at a glance. Routine checks can be carried out remotely. This has been particularly useful for the exclusively remote user operation during the extended access restrictions to the DESY site due to the COVID19 pandemics. It also helped to obtain remotely a quick overview of consequences for the cryogenic installations after power glitches that are reported by an automatic warning system via email. Being a remote access tool to a critical infrastructure, however care had to be taken that no parameters involving personal safety can be modified remotely.

Currently, the Cryogenic Supervision System is running on a PC that is serving as a gateway for remote access, limiting the number of persons who can connect at the same time. A web-based version of the client will be implemented in the near future. It will be accessible from any web browser and without any limitation in the number of users logged in simultaneously. However, only one person can log in as an expert. For diagnostics and fast reaction in case of an emergency situation, this will become a valuable option.

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