VACUUM INTERLOCK CONTROL SYSTEM FOR EMBL BEAMLINES AT PETRA III

A. Kolozhvari, U. Ristau and S. Fiedler
European Molecular Biology Laboratory EMBL, Hamburg Unit, Germany

Abstract

A vacuum interlock control system has been developed for EMBL structural biology beamlines at PETRA III synchrotron. It runs on Beckhoff PLCs and protects instruments by closing corresponding vacuum valves and beam shutters when pressure exceeds a safety threshold. Communication with PETRA III interlock system is implemented via digital I/O connections. The system is integrated in the EMBL beamlines control via TINE and supplies data to archive- and alarm subsystems. A LabVIEW client, operating in TINE environment, provides a graphical user interface for the vacuum interlock system control and data representation.

INTRODUCTION

Three EMBL beamlines for structural biology are in user operation at PETRA III synchrotron on the DESY site in Hamburg. Most of the beamline instruments operate in ultra-high vacuum, and therefore they need an efficient vacuum control system for protection against vacuum incidents. In this paper we describe the second version of the system that is fully integrated into the beamline control environment [1].

CONCEPTS

Controlled Object and Elements

The Vacuum Interlock Control System of EMBL at PETRA III, as any control system, evaluates and changes states of elements constituting the controlled object. The object is a vacuum system of a beamline divided into vacuum sectors, and the elements are vacuum gauges, ion getter pumps, vacuum valves, a front-end and a secondary beam shutter and vacuum sectors.

A sector usually includes X-ray optical instruments operating in ultra-high vacuum, pumps and pressure gauges. It is separated by vacuum valves from the adjacent sectors. A value of pressure in the sector may be obtained from the pressure gauges. Also, if the ion getter pumps are used, the pressure may be calculated from the pump current.

The vacuum valves are the main elements which can be actuated. The control system "by itself" is allowed only to close the valves; they may be opened only by an operator command.

Besides the valves, the control system supplies two permission signals to the Interlock Control System (ICS) of PETRA III, that commands the front-end and the secondary beam shutters of a beamline. In case of withdrawal of the permission signal the ICS must immediately close the corresponding shutter.

The system does not control the ion getter pumps. It only uses data from their controllers for evaluation of states of the sectors.

States of the Elements

A state of an element of the system is a combination of its "physical state" and its control mode. The control mode defines how the system should interact with the element. Three control modes are defined for the system elements: “automatic”, “disabled” and “intervention”.

The physical states defined for the vacuum gauges and ion getter pumps are: “OK”, “Error” and “HV off”.

The physical states of valves and beam shutters are: “open”, “closed”, “undefined” and “error”.

The defined physical states of a sector are: “OK”, “Warning”, “Bad vacuum” - the pressure is above lower threshold, “Very bad vacuum” - the pressure is above ion getter pump shutdown threshold, and “Unknown”.

ALGORITHM

The main task of the vacuum interlock control system is protection of the equipment in case of vacuum incidents. The system continuously monitors the pressure in all sectors of a beamline. If its value exceeds a predefined threshold, the system closes the corresponding valves and isolates the sector.

At each PLC cycle the following actions are performed:

- Reading of the vacuum gauge values and currents and high voltage states of the ion getter pumps. Update of their states and calculation of absolute pressure values.
- Permissions to open beam shutters are set to true. Their values will go to the ICS at the end of the PLC cycle.
- For each sector the system updates its state taking the worst pressure value reading from the gauges, and if they are not available then the one from the ion getter pumps. The system changes a beam shutter permission according to the sector state.
- For each valve, depending on its state and on the states of the connected sectors, the system decides whether the valve must be closed or not and closes the valve if necessary. After that, it checks for an operator command to open/close the valve. If it is possible, the system executes the command and acknowledges it. Otherwise, it sends a negative acknowledgement. If the valve participates in permission to open a beam shutter and if it is either open or disabled, the system keeps the previous value of a shutter permission. Otherwise, it sets the permission to false.

ISBN 978-3-95450-146-5

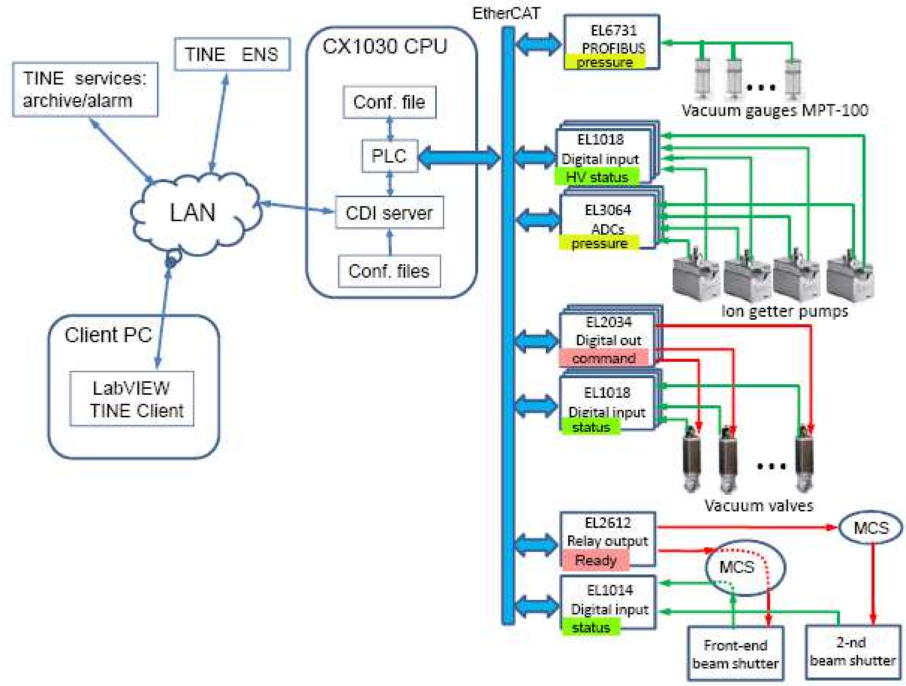

Figure 1: The general scheme of the vacuum interlock control system.

IMPLEMENTATION

The system runs on Beckhoff [2] embedded PC CX1030 CPU module with 32-bits 1.8 GHz Intel® Pentium® M processor, 992 MB of RAM, 7.6 GB compact flash card non-volatile memory, Microsoft Windows Embedded Standard 2009 OS and Beckhoff TwinCAT-2 software.

Basic Hardware Componets of the System

- Pfeiffer vacuum gauges MPT-100 with range $5 \cdot 10^{-9}$ – 1000 mbar. They are connected via profibus interface to the Beckhoff master unit EL6731 for data read-out.
- Varian and Agilent ion getter pumps. The pump controllers provide pump current analog signals to Beckhoff 12-bits ADC EL3064 and logical signals `HVon` to Beckhoff digital input modules EL1018. The data are used by the system for the vacuum state evaluation.
- Different types of VAT vacuum gate valves with pneumatic actuators. They are controlled by 24 V/2 A EL2034 Beckhoff digital output modules. The end switches provide valve status information via the EL1018 digital input modules.

PLC Software and Interfaces

The PLC software is written in Structured Text language for Beckhoff TwinCAT-2 project manager. Two TwinCAT tasks are configured.

The main task performs vacuum monitoring and sector isolation in emergency cases. Also, it executes operator commands for "normal" opening and closing of the vacuum valves.

The second, "slave" task performs data exchange with the system configuration file stored in the local file system.

The general scheme of the system is presented in Fig. 1. The PLC code runs in CX1030 embedded PC and communicates via EtherCAT protocol with the Beckhoff hardware modules connected to the devices. Configuration of the system and parameters of the controlled objects, such as vacuum threshold and status, are defined in the configuration file. External communications are implemented via the chain: PLC code – TwinCAT – ADS protocol [2] – CDI server – TINE [3] protocol.

The CDI (Common Device Interface) server is used as an interface between ADS and TINE protocols. It is a component of the TINE toolkit. The server runs in the same PC as the PLC which simplifies the ADS communications. It sends data to TINE clients in asynchronous mode. The correspondence between TINE properties and the TwinCAT PLC variables is defined in one of the server's configuration files.

Software Client

A TINE client is written in LabVIEW [4] to provide a GUI to control the system. The XControl technology is used. It allows easy adaptation of the GUI to the configuration of a specific system. The main code of the client is single-threaded. It is relatively simple and uses polling to obtain data from the server. The real asynchronous communications between the client and the CDI server are hidden from a programmer by the underlying TINE layer.

Several instances of the client may run concurrently to display the system status but only one may be enabled to control the system.

The client has 4 access levels:

1. monitoring: client performs only status display.

ISBN 978-3-95450-146-5

2. user: client allows the user to perform certain commands needed for normal operation (like venting and evacuating of certain sectors) provided that the action is safe.
3. operator: operations on all vacuum valves are permitted if the system considers them safe.
4. expert: commands changing the control modes of the system objects are permitted. It is potentially dangerous since it gives full access to the system.

Additional windows to display detailed information of each of the sectors and to change status of the objects can be opened with mouse clicks.

SUMMARY AND OUTLOOK

Currently, the vacuum interlock control system is deployed at one of the EMBL beamlines and is operational. Later it will be deployed at two other EMBL beamlines. It has more simple and convenient GUI and has more flexibility in control of the elements in comparison to the first version of the system. Due to the used algorithms, the system minimizes the possibility of operator errors.

During the further operation, as more experience is gained, extension of the system functionalities like extrapolation of the pressure behaviour will be implemented. The structure of the software and the configuration procedure will allow to perform the modifications easily.

REFERENCES

[1] U. Ristau et al., “The Cioncept of EMBL Beamline Control at PETRA III”, MOZ02, Proceedings of PCaPAC08, Ljubljana, Slovenia (2008), p.22-24.

[2] Site of the Beckhoff company: `http://www.beckhoff.com/`

[3] TINE web page at DESY: `http://adweb.desy.de/mcs/tine/`

[4] National Instruments Corporation: `http://www.ni.com/labview/`

ISBN 978-3-95450-146-5