Nuclear Instruments and Methods in Physics Research B 376 (2016) 341–344

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research B

journal homepage: www.elsevier.com/locate/nimb

IGISOL control system modernization

J. Koponen *, J. Hakala, the IGISOL collaboration

University of Jyvaskyla, Department of Physics, P.O. Box 35 (YFL), FI-40014 University of Jyvaskyla, Finland

ARTICLE INFO

Article history:
Received 1 September 2015
Received in revised form 21 December 2015
Accepted 29 January 2016
Available online 26 March 2016

Keywords:
Control system
Hardware
Software
System architecture
EPICS

ABSTRACT

Since 2010, the IGISOL research facility at the Accelerator laboratory of the University of Jyväskylä has gone through major changes. Comparing the new IGISOL4 facility to the former IGISOL3 setup, the size of the facility has more than doubled, the length of the ion transport line has grown to about 50 m with several measurement setups and extension capabilities, and the accelerated ions can be fed to the facility from two different cyclotrons. The facility has evolved to a system comprising hundreds of manual, pneumatic and electronic devices. These changes have prompted the need to modernize also the facility control system taking care of monitoring and transporting the ion beams. In addition, the control system is also used for some scientific data acquisition tasks. Basic guidelines for the IGISOL control system update have been remote control, safety, usability, reliability and maintainability. Legacy components have had a major significance in the control system hardware and for the renewed control system software the Experimental Physics and Industrial Control System (EPICS) has been chosen as the architectural backbone.

1. Introduction

The IGISOL (Ion-Guide Isotope Separator On-Line) [1] research is focused on the properties of nuclei far from stability. Most of the IGISOL research activities utilize the ion guide technique in which target materials are bombarded with ions with energies up to several tens of MeVs, after which reaction products from nuclear fission or fusion are stopped in helium gas, thermalized and reaccelerated again up to 30 keV energy. After the ion guide the reaction products are mass-separated with a dipole magnet, having mass resolving power of about 500, and transported either to decay spectroscopy measurements, or alternatively cooled and bunched with the radio frequency quadrupole cooler-buncher (RFQ) [2] and studied further by the means of collinear laser spectroscopy [3] or JYFLTRAP tandem Penning trap setup [2]. In addition to executing laser spectroscopy after the RFQ, laser studies can also be done inside the RFQ or in the target area. With JYFLTRAP, most of the research activities are related to high precision mass measurements or purification of the reaction products for post-trap decay spectroscopy. The new IGISOL4 facility has been receiving accelerated on-line ion beams since 2012.

Compared to the old IGISOL3, the IGISOL4 facility has drastically larger area accommodating approximately 500 m^2 in three floors. From the technical point of view the increased length of the beam line means more optical beam line elements and associated devices. The total number of monitored and controlled instruments is several hundred, a number that goes up over time with the needs of the facility. When also taking into account the varying research setups the number grows even bigger. Very high ionizing radiation levels in the target section and several high voltage platforms bring additional challenges. All these aspects reflect to site specific demands and increased scale as well as complexity in the facility's control system (CS). The complexity of the CS is going up by the fact that more tasks are needed to be done with more devices and more complex execution logic. To meet many of the stated requirements the EPICS [4] software (SW) was chosen for the core SW architecture of the IGISOL CS.

2. IGISOL control system requirements

Understanding the requirements and defining the specifications are the vital basis for building a CS. In the case of the IGISOL facility the CS requirements are divided into common system requirements, such as safety, usability and maintainability, and site specific needs. Requirements are also specified separately for hardware

Abbreviations: CS, control system; DCS, distributed control system; EPICS, Experimental Physics and Industrial Control System; HW, hardware; SW, software; IOC, input/output controller; PV, process variable.

* Corresponding author.
E-mail address: jukka.ae.koponen@jyu.fi (J. Koponen).

http://dx.doi.org/10.1016/j.nimb.2016.01.046
0168-583X/

(HW), concerning physical devices and signals, and for software (SW), concerning user/operator interfaces and process logic.

The most fundamental requirement for the IGISOL CS is getting as many devices as possible remotely controllable. Remote control eases facility operations as the controlling and monitoring of the devices can be centralized in physical location and in SW logic. In the IGISOL facility remote control has even more importance due to the physical environment, meaning high voltage and radiation, thus all the devices are not always accessible. This relates to the user safety requirements which include e.g. avoiding electric shocks or unnecessary radiation doses.

User safety can also be categorized under a separate safety system but within this paper it is included into a specific HW part of the IGISOL CS which currently has no SW interfaces. In the future user safety related issues are planned to have high level CS SW interfaces for interlock and status reporting, but not for controlling purposes. In addition to user safety also device safety has been taken as a design principle.

Modern remote control means intuitive graphical user interfaces (GUIs) and that contributes to usability. Thus requirements have been stated for GUI design, especially since the staff operating the IGISOL facility is changing on a regular basis. Programmable system management, meaning defining the system parameters and logic by SW, eases the system maintenance so it is in the list of key requirements. Also flexible expandability is required due to the evolving nature of this kind of research facility.

Naturally reliability is one of the key factors in the IGISOL CS as well. During experiments the facility is often run 24 h a day for weeks at a time without interruptions, so the system has to be robust.

Some parts of the IGISOL CS have been considered with the above mentioned principles already during the IGISOL3 time [5].

3. IGISOL control system status

3.1. Hardware – devices, signals and hierarchy

The ion beams produced in the IGISOL facility are guided to the measurement setups through ion-optical beam line elements. The majority of these elements consist of electrodes that are wired to their own power supply units (PSUs). The most of these PSUs are controlled and monitored using analog 0–10 V DC signals. In order to reduce cable lengths and to provide control for the PSUs in high voltage platforms, multiple modular remote input/output (I/O) systems from WAGO Kontakttechnik GmbH have been deployed in the IGISOL area. Each of these systems include I/O modules for 24 V or 5 V digital signals and for 0–10 V analog signals. These remote I/O systems are equipped with Ethernet communication interfaces and are connected to the IGISOL local area network (LAN).

In the case of sextupole ion guide (SPIG) [3], RFQ and Penning traps, radio frequency (RF) signal generators are also needed. These instruments are connected directly to the IGISOL LAN in the case the RF generator has an Ethernet interface. Older RF generator models have general purpose interface bus (GPIB) interfaces and they are connected to the IGISOL LAN via GPIB-LAN gateways. In similar manner, communication to a few devices with serial RS-232 interfaces is established via RS-232-LAN gateways.

The JYFLTRAP setup includes a number of electrodes that need PSUs with more accurate and stable voltage levels. A modular PSU solution from iseg Spezialelektronik GmbH is used in the trap setup. These iseg PSUs have controller area network (CAN) interfaces for remote control, which is implemented using a PC computer that has a CAN interface card. CAN is a fieldbus that allows to connect multiple devices into a single fieldbus. Thus only one signal cable is needed to control several iseg PSUs.

Most of the remote I/O systems used at the IGISOL facility are equipped with interface modules that have no capability to perform logical operations based on the input signals available. A computer program executed in a regular computer or a single board computer (SBC) is performing the computational tasks needed. In a few cases, like target chamber gas feeding control and vacuum system control, more capable and self-sustained programmable logic controllers (PLCs) are used.

The main design aspects of the IGISOL CS HW are the use of robust and off-the-shelf devices with standard interfaces, expandability and Ethernet capabilities. In-house HW design is used only when necessary and mostly for simple tasks physically close to the field side devices. Ethernet as the data transfer backbone brings along highly standardized design of the CS HW as Ethernet capabilities are found from many different types of devices. Thus Ethernet is one way to establish a modern distributed control system (DCS) design where controlling processes can be distributed throughout the system, not only in one single location. The IGISOL CS HW architecture and hierarchy are presented from the device and signal scope in Fig. 1.

3.2. Software – components, protocols and hierarchy

The IGISOL CS software (SW) includes three distinct hierarchical layers given in Fig. 2. Layer 1 consists of GUIs programmed mostly with National Instruments LabVIEW [6] system design platform. LabVIEW is used as the main GUI tool because of its established role in the system development in the facility. Also other tools, such as EPICS Qt Framework [7], have been under consideration and may be utilized in the future. In GUIs the only SW component outside the LabVIEW's own environment is CA Lab [8] interface library between LabVIEW and EPICS. The main design principle for the layer 1 GUI SW is to offer the functionalities required by the system operators but keep the software as simple as possible with no supervisory execution logic attached. In addition to GUIs, also CS archiving processes are placed inside the layer 1 SW.

The main operational logic, i.e. the supervisory processes, of the IGISOL CS is located in the layer 2 SW which relies on the EPICS SW. EPICS utilizes a TCP/IP client–server model which again is used for transferring data between DCS components inside a LAN. EPICS uses its own Channel Access (CA) protocol over TCP/IP to exchange data between clients and servers in the EPICS network. EPICS input/output controllers (IOCs) act as soft real-time servers maintaining a distributed run-time process variable (PV) database of the whole SW related CS. The IOCs are also offering an elegant middleman layer between the field side devices and high level SW.

The lowest layer of SW, layer 3, includes industrial automation SW components programmed with CODESYS [9] platform. Layer 3 SW is located physically closest to the field side devices inside PLCs and includes execution logic in the cases where close and network independent control of the field side devices is required.

The reasons for IGISOL CS to rely on EPICS SW are that it is stable, well-tested and successfully used in a large number of facilities all around the globe. EPICS core SW also offers a remarkable amount of features with no licensing fees. EPICS SW provides many features that one would have to implement otherwise. After device support has been implemented for a specific device type, IOCs can be configured to provide access to multiple devices of the same kind. The configuration parameters include e.g. definitions for alarm limits, safety limits for values, definitions for displaying PVs, and unit conversion parameters.

The layer 2 middleman SW of the IGISOL CS is handled by about 10 different IOC processes divided according to the type of the field side units. IOCs execute I/O tasks and server side logical processing