STATUS OF THE MIGRATION OF THE S-DALINAC ACCELERATOR CONTROL SYSTEM TO EPICS*

C. Burandt†, U. Bonnes, J. Enders, F. Hug, M. Konrad, N. Pietralla
Institut für Kernphysik, TU Darmstadt, 64289 Darmstadt, Germany

Abstract

The S-DALINAC has been in operation for more than two decades. The control system has ever since been an in-house development. This contribution overviews the current status of the migration to a new EPICS-based control system. Several important subsystems have been adapted, but the process has not been completed yet. The general network infrastructure has been restructured in context of the ongoing migration and is also presented.

INTRODUCTION

The superconducting Darmstadt linear electron accelerator S-DALINAC was taken into full operation in 1991 [1]. Two separate control systems, one for beam transport and one for the rf controls, both based on VMEbus computers, were used. The former was upgraded once, with a VMEbus Single Board Computer equipped with a DEC Alpha CPU and running VxWorks [2]. The user interfaces had been developed on a OpenVMS cluster. Communication was carried out via a custom protocol over Ethernet. As the S-DALINAC is an accelerator exclusively developed by students, the life cycle of many subsystems is longer than the time of a full change of the staff. Moreover students can not be expected to have previous knowledge of the VMS operating system or VxWorks which made maintenance and further developments quite difficult.

When extension of the old control system became impossible, the development of a new control server was initiated. Since no real-time requirements for high level control need to be met, an architecture relying on standard PC hardware and TCP/IP was chosen for its low price and the good availability [3]. The resulting client/server control system is still in use. It controls most of the magnet power supplies and the movable scintillation screens used as an optical feedback for the operators. Due to its highly specific hardware, the rf control system still was stuck with the old computer hardware and software.

When the analog low-level rf control system was replaced by a modern digital solution in 2010 [4], a control system which could cope with the challenges of thousands of available parameters and diagnostic values was needed. For its Linux compatibility and its active community EPICS [5] was chosen. Already without writing program code it can be adapted to different needs, since the design allows extensive configuration of all aspects. Even the integration of proprietary hardware interfaces requires only minimal programming effort, as the device support is well separated from the other parts of the system. The EPICS framework and most of the related tools are open-source software. There are no license issues at all.

After first on-site experience with the new control system the process of integrating more equipment unrelated to the rf control system started. A growing number of devices has ever since been integrated and existing single-purpose computer programs diminished leaving an increasingly cleaner operator environment.

HARDWARE

CAN Power Supplies

The S-DALINAC is an electron LINAC which is designed to provide beams of energies up to $130\,\text{MeV}$ and $60\,\mu\text{A}$. A low number of dipole magnets require currents between 50 and $300\,\text{A}$. The lenses, quadrupole magnets and steerers can be supplied with small power supplies ($\leq 10\,\text{A}$ of output current) which therefore contribute to the total number of approximately 200 magnet power supplies by 95 %. For replacement, an in-house development was prefered for cost reasons. The question for the hardware interface could be approached freely. A communication bus allows to connect multiple devices with a single cable and a single connector to the PC. The CAN (Controller Area Network) bus was chosen for its simplicity and cost-efficiency. Microcontrollers whith built-in CAN controller are available. In contrast to ethernet-equipped controllers these are quite low-priced and need less configuration. Figure 1 shows the basic concept of the in-house developed hardware family.

Further Hardware Development

When different hardware was developed in-house later on, the basic design of the power supplies was adopted at its best. That is, not only do they share a CAN bus interface but even the same microcontrollers running the very same firmware. Even though the devices are fundamentally different in purpose, they share basic functionality like setting the power status. The firmware itself determines the type of hardware it is running on and adapts its behaviour accordingly. That is, the individual commands for each kind of hardware are provided.

Among others, the following hardware has been developed taking the same structure as basis:

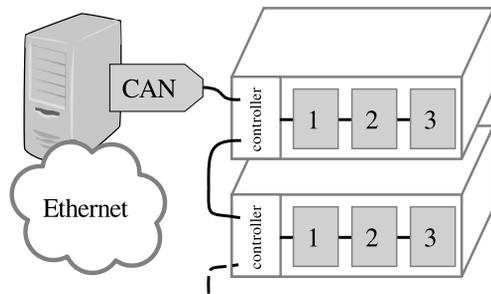- A multi-purpose measurement system which uses different modules to digitize voltages and currents, but

Figure 1: Schematic layout of the hardware. The CAN bus is connected to the crate controller, a dedicated unit which has administrative functionality only, and can be daisy chained to the next crate. Inside the crates, the bus is extended on the backplane to the single slots. Thus, the wiring is kept clear. A PC running an appropriate IOC communicates with the devices and provides an EPICS interface for remote clients via Ethernet.

also allows four-terminal sensing for precise resistance measurements.

- Controllers triggering the pneumatics driving the scintillating screens.

- The most complex type of hardware in this development line is the above-mentioned rf control system. The fast feedback control algorithm is implemented in an FPGA.

EPICS AT THE S-DALINAC

Custom Device Support

The described hardware is connected to the PC by a commercial CAN interface. A so-called device support software module connects it to EPICS.

Although CAN bus device support modules for cards of different vendors are available, a new module has been developed. The socket-based approach used with our IOCs (Input Output Controller) is described in more detail in a dedicated contribution [6]. The major advantage over other implementations is the possibility to connect the IOC to a certain CAN interface while still being able to connect diagnostic tools to the very same software interface. Apart from that, independence from the PC CAN adapter manufacturer is gained.

Another type of device support is required for the digital low level rf system. It allows bit level diagnostics at the full sampling rate of 1 MS/s and a resolution of 18 bit. A USB 2.0 interface is used to transfer the data to the PC. The corresponding device support process provides streaming data via TCP/IP to arbitrary clients. After reducing the data rate the data is also fed into EPICS records. These are used for monitoring by the operator and can also be archived.

Input Output Controller

Several IOCs are in use at this time. They are executed either on physical or virtual machines. The rf control sys-

tem, the thermionic electron gun and the multi-purpose measurement system have completely been migrated to EPICS. Each system has a dedicated IOC.

The large dipole power supplies and many vacuum gauges are equipped with serial ports like RS-232. These are connected to commercial device servers that make the serial interfaces accessible over Ethernet. An IOC utilizing the StreamDevice device support [7] runs on a virtual machine.

The IOC configuration is obtained from a relational database. A PostgreSQL Database holds information about all accelerator-related devices. It is divided into tables, each containing the equipment of a single domain, e.g. *beam diagnostics* or *beam transport equipment*. The information includes the electrical connection data, the type and name of the associated magnet and the current limits. When building an IOC this information is retrieved by a Perl script and is used to create substitution files automatically.

User Interface

As graphical user interfaces (GUI) the Eclipse-based Control System Studio (CSS) is used. A custom product has not yet been created. We so far rely on css-nsls2, which offers the *Best Operator Interface Yet* (BOY) and the DataBrowser plugin [8]. Due to the fact that programming is unnecessary, Operator Interfaces (OPIs) are changed and optimized on a regular basis and many are created to simplify special activities like the calibration of rf systems.

In future, a custom product will be built from the source repository. It might be quite similar to css-nsls2, but will carry all the individual configuration, which is for example necessary to access the archived process variables.

For the controls of the magnet power supplies, operators prefer rotary knobs during beam optimization. The knobs used at the S-DALINAC combine the features of setting a value to a particular channel as well as switching between different devices. An appropriate EPICS client application is under development and will complete the migration of the magnet power supply controls.

SERVICES

EPICS Specific Services

An archiver solution with PostgreSQL back end on has been put into operation recently. It is described in detail elsewhere [9].

State machines are implemented using the EPICS Sequencer module [10]. Since the S-DALINAC uses rf superconductivity, a fine-tuning system is necessary. It is based on magnetostrictive elements which are mounted next to the cavities inside the cryostat. To avoid frozen magnetic fields in the cavities during the next cooldown, the tuners need to be degaussed before warming up the cryostat, when maintenance is scheduled. A state machine cycles the tuners power supplies in a convenient way on demand and

keeps track of the usage of the tuners. Further applications of the sequencer are under development.

General Services

A build-server retrieves source code from a revision control system and provides many applications as Debian packages. Together with a Debian FAI server (Fully Automatic Installation [11]) the setup of ready-to-use machines is a matter of minutes. This technique is used on a regular basis when hardware is replaced or the installation procedure for a certain machine has changed considerably.

A MediaWiki is hosted for arbitrary user documentation. Electronics engineers and control-system programmers share various information with users and eventually update it while keeping the version history. This is especially helpful with rapidly-changing student personnel.

The documentation of bugs is achieved by a bugtracker. They can be categorized and assigned to a certain developer.

INFRASTRUCTURE

Network Layout

A subnet holds all devices and computers which are directly required for the operation of the accelerator. Therefore all IOCs are operated in this subnet. The control systems of the various experiments use a separate network segment. The exchange of information, held as EPICS process variables, between the subnets is required. Two *CA Gateways* [12] are in operation facilitating read-only access to process variables that are available in the accelerator's subnet from the experiments' subnet and vice versa. Read-only access is also possible from office computers.

To further improve the network security, the setup of a so-called demilitarized zone (dmz) is convenient. A number of services needs to be available in both, the accelerators subnet and the public network. This includes the database server, the build-server, the Fully Automated Installer and potentially a webOPI server. These will be placed in the dmz which is a separate network segment.

Virtualization

When no direct hardware access is needed a service can run on a virtual host. This applies to the above-mentioned Wiki software, the bugtracker, the build server, the Fully Automatic Installation server and the *CA Gateway*. Even the IOC which uses the StreamDevice device support is solely connected via Ethernet to the device servers. Thus it is running on a virtual machine.

FUTURE WORK

There is no appropriate handling of warnings and errors from the beam-line equipment up to now. An alarm system toolkit like BEAST is a possible solution here.

Scintillating screens can be lowered into the beam pipe to allow determination of beam position and beam shape. Both, the controllers switching the pneumatics and the

video multiplexer switching the corresponding video signal, are not yet integrated into EPICS.

CONCLUSION

During two years of operation in a production environment at the S-DALINAC the EPICS based control system proved to be a stable solution. The progress of migration is still ongoing, but is approximately half-finished.

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REFERENCES

[1] A. Richter, in: Proceedings of European Particle Conference 1996, Barcelona, Spain (Institute of Physics, London, 1996), pp. 110-114

[2] S. Richter, "Design and implementation of a new local control system at the S-DALINAC," Dissertation D17, TU Darmstadt, December 2000

[3] O. Patalakha, "Design and implementation of a modular client/server control system for the S-DALINAC," Dissertation D17, TU Darmstadt, July 2006

[4] M. Konrad et al., "Digital base-band rf control system for the superconducting Darmstadt electron linear accelerator," Phys. Rev. ST Accel. Beams 15, 052802 (2012)

[5] Experimental Physics and Industrial Control System, http://www.aps.anl.gov/epics/

[6] C. Burandt et al., "SocketCAN device support for EPICS IOCs", THPD13, Proceedings of PCaPAC'12, Kolkata, India.

[7] EPICS StreamDevice, http://epics.web.psi.ch/software/streamdevice

[8] Control System Studio, http://cs-studio.sourceforge.net

[9] M. Konrad et al., "Control System Studio Archiver with PostgreSQL backend: optimizing performance and reliability for a production environment," WEPD03, Proceedings of PCaPAC'12, Kolkata, India.

[10] EPICS sequencer, http://www-csr.bessy.de/control/SoftDist/sequencer

[11] Debian, Fully Automatic Installation, http://fai-project.org

[12] EPICS: The Process Variable Gateway, http://www.aps.anl.gov/epics/extensions/gateway