REQUIREMENTS AND SOLUTIONS FOR ACCELERATOR CONTROL SYSTEMS

D. Anicic, T. Blumer, I. Jirousek, H. Lutz, A. Mezger

PSI CH-5232 Villigen PSI, Switzerland, Accelerator Control

Abstract

Throughout the life cycle of control systems, we are faced with the question of what fabulous new piece of hardware or software should be used and how to integrate this into a viable system. Accelerators cover a wide range, from simple cyclotrons for isotope production, to cascades of cyclotrons for variable energy and multiple particles, this precludes a standard answer for all cases. The system requirements according to the purpose and nature of the accelerator are analyzed and we try to extract some guidelines for implementation, development and maintenance of the appropriate control systems. We then try to analyze present trends in a selection of fields like operating systems, commercial systems, software sharing, field busses, etc.

1 GENERAL

Our accelerators cover a wide range, from simple cyclotrons for isotope production, to installations with cascades of cyclotrons for variable energy and multiple particles. Machines are operated in hospitals, universities or research institutes. They may be static installations or machines under development, operated by skilled personnel (physicists, engineers and technicians) or by the unskilled users that have no insight into cyclotrons (nurses etc.)

These wide differences in usage and complexity of machines imply that they also require different control systems.

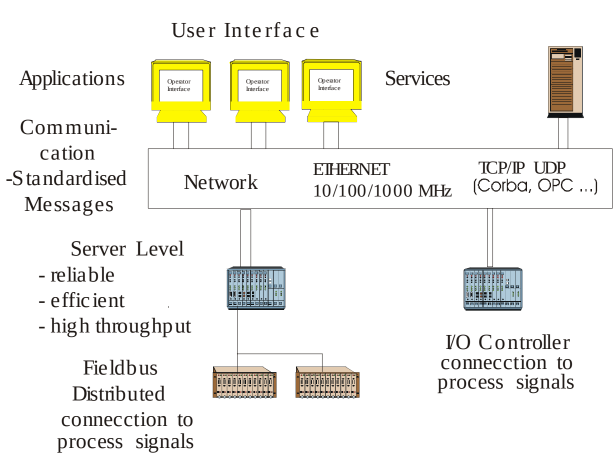

Figure 1. Typical accelerator control system architecture.

2 LIFECYCLE OF THE CONTROL SYSTEM FOR AN ACCELERATOR

The lifetime of accelerators is fortunately much longer than the time that commercial control-system components and specially computers are maintainable. The time of availability to buy a specific piece of hardware is sometimes even shorter. This is a serious problem we have to cope with. Already during the planning of new installations or the implementation and commissioning phase of a machine components may get out of service life. A modular design based on basic and proven standards without exotic components will help you. When maintaining an older installation, in house expertise for repair and for the occasional development of special purpose components may prove itself to be very efficient. Most systems using CAMAC depend on this in house experience.

In case of a mayor machine upgrade, the state of the control system and the requirements for the upgraded machine usually imply a redesign. A careful planning of the upgrade and the transition phases within are essential. We estimate that our positive experience with the past upgrades can best be characterized with the following keywords: distributed architecture, device oriented process model, modular design, standardized and message based communication, database for system configuration etc. See Fig. 1.

3 CONTROL SYSTEM SOFTWARE

The Control System SW is the user tool, the only window with the view on the accelerator. It has to cover all needs for every user.

The beam user, the experimenter, just needs concise information: if the beam is available and if it has the required properties. In some cases he wants to set a few parameters.

The machine operator wants ergonomic graphical machine presentation, self-running systems, prompt reactions to commands, and all of this customizable.

The machine physicist would, in addition to operator, need more detailed machine information, archiving and logging data available online and access to the configuration database. He needs an extensible control system to easily integrate any needed measurement or control devices.

The hardware people, responsible for electronics and devices need even more insider information, and the

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access to the built-in test, diagnostics or HW configuration parameters. The later features are usually not fully supported in our control systems.

And finally, the control system SW designer would like to produce a clean and maintainable software structure. He would expect to be given nicely and properly defined HW interfaces and data types as well as state of the art, up to date and modern computing resources. It should be possible to monitor the control system functionality itself, in order to detect malfunctioning or when extending functionality according to the user requirements. The designer would now and then like to have the opportunity to redesign the software and to publish an article for his own satisfaction.

In practice, the control system software is a superset of the above-mentioned properties. It is often influenced by the restriction to stay compatible with previous versions of the control system and usually inadequate resources, particularly manpower. Within these limits we try to please all of the users. The outcome is a working system we tend to call A Modern Control System.

4 FIELD BUSSES

Technically, a present accelerator control systems follows the three-layer standard model architecture:

- The sensor/actuator bus layer with devices
- The field bus layer for the process control with accelerator objects
- The network is the visualizations layer with control GUIs

The field-buses are powerful data acquisition and networking systems that connect up to 32000 intelligent nodes with I/O modules directly connected to the control-node. The control-node interface is connected to all devices trough a twisted pair or fiber-optic cable. On the control-node, the field-bus Network Service Management tools are used to register each node. Field bus technology offers a complete network system in hard- and software and eliminates, in most cases, any need for network programming. Many field-bus boards are commercially available, however it is also relatively easy to interface own designs to the specific bus control interface. Table 1 shows the comparison of few sensor/actuator busses witch are today not standardized but only recommended for accelerator and industry control systems. The name field-bus for this sort of busses is incorrect; it belongs to the three-layer standard model architecture.

4.1 Complete Systems

Most of the control systems in the industry use PLCs (Programmable Logic Controller) as process control and SCADA (Supervisory Control And Data Acquisition) software tools & packages as process supervisor.

PLCs are diskless compact computers plus hardware interfaces (I/O models) for the process level. They are generally used for automatic control (input/output, closed loop control, interlock, vacuum control etc.). PLC's may be used as:

- Standalone, autonomous and solution, where secure and remote computer independent operation is needed
- A field-bus networked solution

Table 1. Comparison table of “Field busses”

Fieldbus (sensor/actuator)	**cable type**	**speed (kBit/s)**	**byte/frame**	**distance (m)**	**Nr. of node**
PROFIBUS-DP	Cu 150Ohm	9.6-12000	1 – 255 -Synchronisation: at least 33 bits idle -FCS Frame check - ≤ 127 Mess./s	1200 – 200	127; -multi master; master-slave - brodcast and multicast
	fibreoptic	9.6 – 1500		4800 – 200	127
CAN 2.0B	Cu / fiberoptic	50 – 1000	6 – 14 - CSMA/CA bus control - priority of transmission - CRC error detection - real time communication (remote-frames) - ≤ 9000 Mess./s (1Mbit/s)	1000 – 40	32; -multi master; master-slave - brodcast and multicast
InterBus-S	Cu (point to point)	up to 500	max 4096 I/O - CRC error detection - 136 Mess./s (2048 I/O)	13000 à max. 400m	256; single master
LON	Cu / fiberoptic	0,61 – 1250	9 – 248 - CSMA/CA bus control - priority of transmission - CRC error detection - < 100 Mess./s	depend of cabel type	32385/Domain (48 bit); multi master

- Ethernet based. The PLC manufacturer provide their own communication protocol based on standard TCP/IP and on IEEE 802.2 frame, the upper portion of the OSI data link layer

The dominating PLC manufacturers in the European market are Siemens and Schneider. The S7 PLC product line from Siemens comes with powerful development and diagnostic tools. A big variety of modules are available (position and PID controllers, etc).

PROFIBUS-DP is the well-supported natural method of external connectivity. PLC periphery can be transparently extended by ET200 type of distributed I/O modules. Schneider is the second player in the European PLC market and comes with the TSX Premium PLC product line.

PLCs are integrated to SCADA either by use of particular SCADA drivers, by use of a special communication cards, or OPC (Object Linking and Embedding for Process Control).

A general architecture of a SCADA environment is shown in figure 2. The Client layer makes the man machine interaction and the Data Server layer handles the process data control activities. The data servers communicate with field objects (devices) through process controllers. Dedicated Servers are used for particular tasks (data logging, configuration database). In general a SCADA system provides:

- Client-Server and Server-Server networked communication, which is in general on a publish-subscribe and/or event-driven base, over TCP/IP
- The Device access via Data Server is done by polling and/or event-driven, with time-stamping
- A Driver communication toolkit for PLCs and field-buses
- Interface library (API/DLL library, OPC, ODBC, ASCII import/export, DDE, OLE, ActiveX, JET)
- Real-time Database + RDBMS support

Instead of programming code as in conventional systems one has to switch to configuration tasks. This includes:

- Development of templates and symbol libraries, like power-supplies, racks, pumps, magnets
- Implementation of standard interface methods to external systems
- Definition of system architecture, splitting functionality between SCADA and other systems
- Definition of Guidelines (look and feel, access control, alarm priority)

Benefits of using SCADA systems are:

- A rich set of functionality extensively developed over many years
- The End User development amount is minimal if suitable engineering was done
- The reliability, robustness of the systems is very high. They are used for mission critical industrial processes control
- Support/maintenance provided by vendor

A big disadvantage is that almost all SCADA systems run under Windows NT only. VME & CAN busses are often not supported as field-bus components. Some SCADA products:

- WINCC, from Siemens. It integrates a Graphical Editor, the SYBASE database for storing process variables and alarms, Alarm-system, support a lot of industrial networks and PLC types
- PVSS, from Austrian ETM. It has been chosen at CERN for the LHC (Large Hadron Collider) experiment control system
- IGSS, from Seven Technologies, Denmark. This package has been selected at PSI for the PROSCAN project for supervision of the Proton-Cyclotron

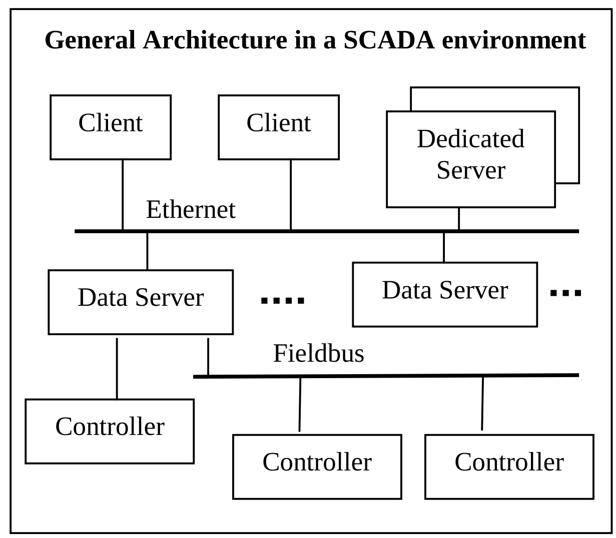

Figure 2 General architecture in a SCADA environment