Upgrading the Control System for the Accelerators at The Svedberg Laboratory

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Abstract

Two accelerators at The Svedberg Laboratory in Uppsala, the Gustaf Werner cyclotron and the CELSIUS ring, will get a new control system. At present both the cyclotron and the ring have their own control systems based on S99 and PDP-11 minicomputers respectively. There are also a number of subsystems which are controlled separately from the stand-alone PC based consoles (ECR ion source, electron cooler, vacuum system). The goal of the rejuvenation is to integrate all existing control systems and provide the new system with an uniform operators interface based on workstations. The obsolete S99 microcomputers will be substituted with a VME system and all subsystems will be connected to the Ethernet. The upgrade strategy enabling the transformation of the system without any long shut-down period is discussed. Hardware and software planned for the upgrade is presented together with a discussion of expected problems.

1. INTRODUCTION

The control systems for Gustav Werner cyclotron and the CELSIUS ring have been designed at different times. The cyclotron [1] after a major rebuilding started its operation in 1986 The main cyclotron control system, based on S99 microcomputers, covers the cyclotron and all beam lines. The radiation protection system for the whole laboratory area is also based on S99 microcomputers with an 286/PC as a console. Another 386/PC connected to a Programmable Logic Controller (PLC) controls the external ECR ion source. The CELSIUS control systems is based on the LEAR control system from CERN slightly adapted to our needs. The system is based on a PDP-11/73 minicomputer connected via CAMAC hardware to the accelerator equipment. This system enables to control all function generators and all static parameters but these for the electron cooler. The electron cooler is controlled independently from an IBM PC. Some other subsystems, both on the cyclotron and the storage ring side, are also controlled from the 286/386/PCs. From the very beginning the work on these control systems was completely independent - there were separate teams for each machine (the cyclotron and the ring) and there was no cooperation between them. It all resulted in two distinct control systems with different philosophy and incompatible hardware solutions. After achieving the production stage of operation by the cyclotron and approaching the same stage by the CELSIUS ring a need for a common control system became obvious. Some organizational changes (creating one control group for cyclotron and the ring) should help to achieve this goal. The cyclotron and the ring is each controlled from its own control room with very limited possibilities to control or even only access the information from the other machine. This is highly unsatisfactory and the new control system will enable to control both machines from either of the control rooms. Some other features like beam sharing will be added. In order to improve the situation we plan to connect all substems together via an Ethernet and add a new user interface in the form of UNIX workstations. Some of the old S99 microcomputers will be substituted by a VME system running VxWorks. Such approach will enable us to achieve our objectives with minimal changes in the front end level and without any long shut down periods of the accelerators.

2. EXISTING CONTROL SYSTEM ARCHITECTURE

A. Cyclotron

The cyclotron control system is based on Texas Instrument (TI) microcomputers. At the top level there are three TI S99 microcomputers. The control system data base resides in one of the S99 systems, while the other two are mainly used as operator interface to the system. At the hardware level most of the equipment is connected to the control system by an in-house-built microcontroller called General Interface (GI). A single euro-board includes a TMS9995 microprocessor, analog and digital I/O channels, a terminal port for local control and a custom-designed serial communication bus. Up to 31 devices can be connected to this bus. Special interface boards (also in-house-built) are used to connect the bus to the S99 systems. There are about 150 GI's in the system. They are mainly used in the beam transport- and RF-system. Apart from the GI-controllers two industrial PLC units (Modicon 484 and 684) are used in the vacuum- and RF-system, fig. 1.

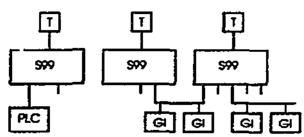

Figure 1. The main control system of the cyclotron.
T - terminal
PLC - Programmable Logic Controller
GI - General Interface (front-end controller)

The S99 systems runs TX990, a multitasking operating system from TI. Today both hardware and software support for S99 is very limited. Most of the control system software is written in assembly language. All this makes maintenance difficult and time consuming.

The radiation protection system also uses two S99 microcomputers. One S99 system handles the interlock and access control to the various experimental areas. The other monitors the radiation level by means of some 50 radiation detectors distributed in the laboratory. A 286/PC is used as operator interface. The radiation levels are continually logged to the PC disc. No distributed I/O (GI's) are used in this system, thus some 600 digital I/O signals and 50 counters are connected directly to the S99-systems, fig. 2.

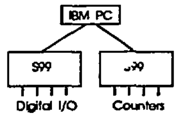

Figure 2. The radiation protection subsystem.

In 1989 an external ECR ion source [2] was added to the cyclotron. A Siemens S5 -115U [3] PLC is used as front-end. For operator communication a 386/PC is connected to the PLC system by means of a Siemens CP524 [3] communication processor, using an RS 232 channel to the PC. Most of the hardware is connected to the PLC but a few devices are connected directly to the PC using RS232, fig. 3.

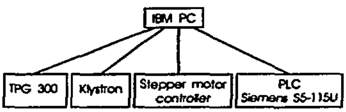

Figure 3. The ECR control subsystem.

MS-DOS was chosen as operating system for the PC, mainly because of the large amount of inexpensive software available for this environment and because the staff was already familiar with this operating system. Another alternative would have been to use a real-time multitasking operating system. This would probably have resulted in a more efficient system but at a higher cost. The present solution was considered adequate since the ion source control handles a relatively small number of parameters (<100).

The control program is written in Microsoft C. To simplify programming, a library of process control routines was written. This library allows creation of multiple threads of execution within a program. Threads can communicate through shared variables or message queues implemented in the library. The threads are scheduled using a nonpreemptive round robin algorithm. This eliminates the need for mutual exclusion mechanisms when accessing shared data. Scheduling only occurs when a thread makes a blocking call to the library (for example reading from an empty message queue). Driver routines for the RS 232 channels are also included in the library. This enables the driver to block a thread waiting for an I/O operation to complete.

B. Storage ring

The control system of the CELSIUS ring covers all function generators (25) and static power supplies (control and/or acquisition) in the ring (about 100), a vacuum system of the ring [4] (about 350 digital inputs/outputs plus 16 analog inputs) and the timing system. The whole system consists of three parts: main control system (fig. 4), electron cooler control (fig. 5) and vacuum control.

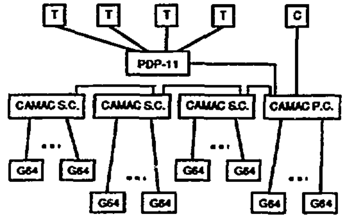

Figure 4. Main control system of the ring.
T - terminal, C - console,
CAMAC PC, CAMAC S.C - parallel and serial crate
G64 - front-end controllers in G64 standard

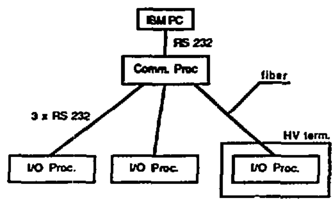

Figure 5. Electron cooler control.

The front-end level in both the main control system and the cooler control system is based on the G64 standard. The vacuum control is executed by a programmable logic controller (PLC). The PC in this case, connected to the PLC via RS 232 serial line is used only as an operator console. The PDP-11 is running under RSX11-M V4.2 operating system and DECnet. The kernel of the control system and many applications are written in MACRO-11 assembler. Other application programs are written in FORTRAN and Pascal. The PCs are running under MS DOS and the control programs are coded in Turbo Pascal. There are several data bases and data base management programs. In the main control system there is a database for static parameters, for dynamic parameters (vector tables) and for the timing system. The cooler control system has its own data base. All these data bases have different structure and contains various fields needed for the control tasks. The operator interface is also different for each system. The main control system have a console with a touch screen, numerical keypad, knobs and a semigraphical color display. The touch screen menus have a tree structure with 16 buttons on one page. The buttons can be used to pick up the parameter for control, to start an application program or to choose another page. A number of application programs have a text oriented user interface and are run directly from the terminal. The user interface of the electron cooler is based entirely on the PC working in the text mode. The operator can display up to 20 parameters on the screen. The absolute and incremental control is possible from the keyboard. Commands to the control programs are invoked by the function keys. The vacuum control system has a graphical user interface. The status of the vacuum system is presented on the screen with dynamic symbols (changing color or/and shape) on top of the static picture. The operator communicates with the system with use of dialogue boxes, buttons, text input fields etc.

3. UPGRADED CONTROL SYSTEM

A. Hardware

The hardware configuration of the upgraded control system is presented in figure 6. All control computers will be connected to a segment of the Ethernet which is isolated by a LAN bridge from the university network. A repeater must be used because of segment length limit. The front-end level of the control system will not be changed with an exception of a limited number of low level controllers which should enable switching between several control values synchronously with the ring acceleration cycle. This modification is going to support beam sharing between the storage ring and other cyclotron users as well as switching the settings of the electron cooler between injection energy and flat top energy. The switching will be triggered by external pulses from the timing system.

The changes in the hardware of the next level - local process computers, will be more significant. The S99 systems in the cyclotron control will be replaced by a VME system. A Force CPU-30 [5] will be used as local controller. Due to the large installation base of the GI-controllers they will be kept in the upgraded system. A new version of the GI-communication bus interface, adapted to the VME-bus, have to be manufactured in-house. RS 232 and Ethernet interface are included on the CPU-board. All PCs will be supported with the Ehternet controllers. An upgrade of some PCs based on the 80286 processor to 80386 with at least 2 MB RAM is necessary.

The radiation protection system will keep the S99 system as hardware interface since extensive rewiring will otherwise be required.

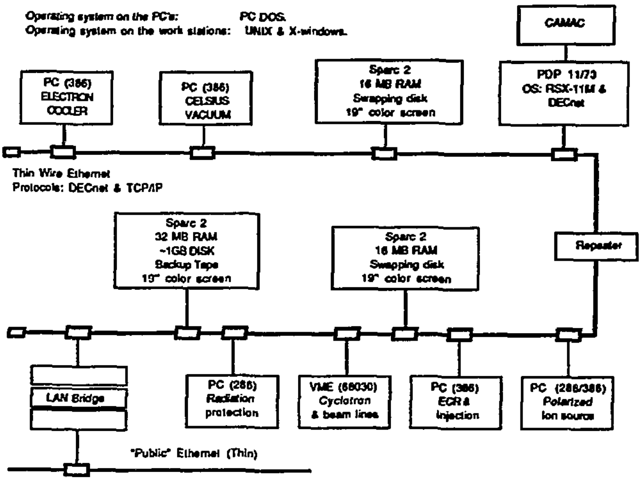

Figure 6. The layout of the upgraded control system.

An additional external polarized ion source [6] will be installed in the beginning of 1992. The ion source is bought as a "turn key" system including control system from Balzers/Pfeiffer. It uses a Siemens S5-135U [7] PLC as front-end and a 286/PC for operator communication.

The top level (user interface) will be based on Sun Sparc 2 workstations equipped with 19 inch color screens. We assume that the mouse and the keyboard will support satisfactory operator interface.

B. Software

The main effort in upgrading the control system lies in the software. Our strategy is to preserve as much of existing investment in the control software as possible. However, a considerable part of the programs will have to be rewritten or moved to another platform. Most of the programs on the workstation must be written from scratch. We have chosen TCP/IP as a communication protocol between the workstations, PCs and VME system. For communication with the PDP-11 we will use DECnet.

The VME system will run the VxWorks[1] real time operating system. The data base will be similar to the ECR ion source data base structure, with the addition of support for multiple control values to a parameter to enable "beam sharing". VxWorks is a "UNIX like" operating system. This means that program modules can be written and roughly debugged on the UNIX workstation, then recompiled and loaded in the target system.

To minimize the use of the poor software development environment in the S99 system, the radiation protection control program will be moved from S99 to PC level. The S99 will only be used for transfering the system I/O image between the PC and the actual hardware. The I/O image mapping server in the S99 will be unaware of the PC application program structure , thus enabling changes in the application without modifying the S99 software.

The programs running on the PC will be modified in such a way that they will be able to get requests from the network and send replies to the callers. The socket interface will be used. The network software we use (PC/TCP for DOS) can support up to about 20 open TCP connections. Most of the connections will be used by application programs and one is reserved for alarm and warning channel to the alarm server on the workstation. The existing programs should still perform all functions as without the network interface. This should allow to gradually move control from the PC to the workstations when the relevant programs on the workstation will be ready and thoroughly tested. We plan to use the same communication procedures and algorithms on all PCs. The programs written in Turbo Pascal will be rewritten to MS Pascal to enable easy linking to the PC/TCP network library.

The polarized ion source uses Wizcon [8], a commercial control system software package. This product have built in support for remote control nodes, using the Netbios communication protocol. This will present a problem since the control system network uses only TCP/IP and DECnet.

The data-base in the workstation will contain only information needed by the application program to access the parameter. All low level internal characteristics will be hidden to the application. There will be no global "life" data base with all parameters continually updated on the workstation. The application programs will get this information from the lower levels on request. The alarm server will listen to the information coming from the different nodes and inform the user of possible problems. This task should also check if all nodes are alive.

We will use SL-GMS [9] as a tool for creating the user interface. The GMS is a software tool kit for building dynamic graphical 2D man-machine interfaces. It was chosen mainly because its flexibility and good compatibility with the X environment.

4. SUMMARY

The work on upgrading the control system has begun about 6 month ago. During this time the requirements for the new hardware and software were specified. We stressed the necessity of using commercial, wide spread and well supported hardware and software. Most of the hardware is already in place or ordered. All computers have been connected to the Ethernet and some tests with the network communication programs have been performed. At the moment we work on the structure of the high level data base and communication protocols. The first program which we plan to write is a synoptic program which will show the status of any part of the accelerators and enable to control selected parameters. Next the application programs from the PDP-11 running on the console will be moved to the workstation. At the same time the work on moving the main cyclotron control to the VME standard will start. The programming and testing will be done on a development system not connected to the cyclotron. After positive tests the system will be installed on the target VME system. The alarm server, the archive program must also be written as soon as possible. As a last step we consider to move most of the application programs running on the PDP to the workstation. Most of them are terminal oriented, so in the transition period we can run them in the terminal emulation window.

The main problem we have to face in upgrading the control system is the incompatibility of existing data bases. This we plan to overcome by creating the new, high level data base for the programs running on the workstation, common for all parameters independently of their physical location. Another problem we meet is the limited pool size in the RSX-11 operating system. This limits the number of tasks which can run on the PDP and special attention must be paid to programming network servers, allowing only one instance of the task. We expect some problems with the RAM size limit imposed by the MS DOS, especially if we would like to keep all the functionality of the existing programs running on the PCs.

[1] VxWorks is a trademark of Wind River Systems, Inc.

5. REFERENCES

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