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A USERS VIEW OF THE SPS AND LEP CONTROL SYSTEMS

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Abstract

Every accelerator has a control system; at present the SPS has two, both of which are needed to run the machine. Consequently a user of the SPS / LEP complex has to be concurrently familiar with three control systems. While this situation brings problems it allows, even forces, comparison between the different systems, which in turn enriches the user viewpoint.

This paper assesses the SPS and LEP control systems from the point of view of the user, who may be an equipment specialist, operator, accelerator physicist or combinations thereof.

1. Introduction – what the accelerators do

Exploitation of the two large accelerators at CERN is a varied business. For the SPS in 1991 this amounts to running as a fixed target machine for over half the year, providing either protons (during 21 weeks) or sulphur ions (during 6 weeks) to the physics community. In conjunction with this the SPS acts as an injector to LEP, providing leptons in an interleaved repetitive supercycle. Furthermore about 15% of the fixed target running time is given over to machine development periods, when the SPS is required to run in some non–standard way, mostly as a testbed for the LHC. Finally, the SPS is also used in the other major mode of operation, as a proton–antiproton collider, for about 5 weeks.

In parallel with all of the 27 weeks of SPS fixed target running, LEP is taking beam either for Z^0 production or for a substantial machine development program, the latter amounting to about 30% of the total LEP running time.

For both machines, although mostly for LEP, installation and testing of new equipment is carried out throughout the year.

This diversity of operations and machine improvement is carried out from a common central control room, with the same teams being responsible for both the SPS and LEP. In particular, one group run the SPS in a variety of modes of operation throughout the year as well as running LEP. This means that these personnel have to be familiar with the different control systems used to interact with the accelerators. The same is true of the personnel responsible for equipment commissioning.

2. Overview of control systems available

From 1975 the SPS has been controlled, either exclusively or partially, via a system based on Norsk Data ND100 computers connected in a TITN star configuration [1]. The computers run SINTRON and the programmers are provided with the NODAL interpreter, libraries of graphics primitives and data modules and a means of calling FORTRAN executables [2].

From 1985 the major new requirement for SPS to provide beams to LEP meant a complete rewrite of the applications software. This was undertaken in a UNIX environment on an Apollo network, with C as the main programming language and Apollo–Dialog for the user interface. In the first instance access to the hardware was via a gateway into the existing TITN system. More recently the possibility exists to access some equipment completely independently from the TITN system, using the same overall Token Ring architecture as for LEP (see below).

Presently the SPS is run using a mixture of purely TITN (30%), Apollo via the gateway into TITN (50%), and purely Apollo Token Ring applications (20%) (see figure 1).

LEP applications also run on an Apollo network, with C as the main programming language and Apollo–Dialog for the user interface. All the Apollos are connected on a control room Token Ring, with communications out into the field through a bridge to a machine Token Ring running around the accelerator [3] . At several points around the ring there is a further bridge or gateway into either a regional Token Ring or an Ethernet network. Connected to these local area networks is a variety of configurations, allowing access into the hardware via several different equipment control assemblies, mostly using the MIL–1553–B standard (see figure 1).

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Experience Controlling the LAMPF-PSR Accelerator Complex*

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Abstract

In recent years, control system efforts at LAMPF have emphasized the provision of uniform control for the LAMPF linear accelerator and associated beam lines and the Proton Storage Ring and its associated beam lines. The situation is complicated by the presence of several control philosophies in the operator interfaces, data base mechanisms, and front end data acquisition and control interfaces. This paper describes the current system configuration, including the distributed operator interfaces, the data and control sharing between systems, and the use of common accelerator diagnostic software tools. Successes as well as deficiencies of the present system will be discussed with an eye toward future developments. *

I. BACKGROUND

The Clinton P. Anderson Meson Physics Facility -- also known as LAMPF, the Los Alamos Meson Physics Facility -- is composed of an 800 MeV proton linac plus associated beam lines and targets, and an 800 MeV Proton Storage Ring (PSR) plus its beam lines and a neutron spallation target that serves the Los Alamos Neutron Scattering Center (LANSCE). The linac accelerates beams of H+, H-, and polarized H- (referred to as P-) ions up to 120 times per second in pulses of up to 1000 microseconds width. The average H+ beam current can be as much as 1 mA. The proton storage ring serves as a beam compressor, taking a full H- macro-pulse from the linac and ejecting it in several hundred nanoseconds.

When LAMPF was built in the 1960's it was one of the first accelerators to be designed for computerized control. Since the IEEE CAMAC standard did not exist at that time, a significant amount of effort went into the design and construction of LAMPF-specific data acquisition hardware. The system that resulted was called RICE (Remote Instrumentation and Control Equipment). RICE hardware is still used for more that 60% of the linac equipment. Over the years, the control system was expanded to include CAMAC hardware accessed on demand through remote computers. With the addition of remote operator consoles, the initial star architecture has evolved into a much more distributed configuration.

The Proton Storage Ring was designed in the early 1980's to be independent of LAMPF with a separate control room and beam lines. As a consequence, the PSR Control System was designed and implemented with only minimal consideration of LAMPF requirements. The PSR system did provide recognition of its effect on linac timing requirements and it used a device naming scheme that was similar to LAMPF's. The PSR system emphasized continuous update of a centralized database.

In 1988, responsibility for the Proton Storage Ring was transferred to LAMPF. This paper describes the present configuration of the two control systems and the attempts that have been made to integrate them in a useful manner. We conclude with a brief description of our plans for the future. More information about our plans can be found in a companion paper at this conference [1].

II. CURRENT CONFIGURATION

A. LAMPF Control System (LCS)

The evolution of the LAMPF Control System (LCS) has been described in detail elsewhere [2-4]. The LCS is currently composed of a network of VAX computers connected via an Ethernet using DECnet for communications. Computer systems in the LCS network are of two types, (Figure 1). A typical LCS operator console computer runs VMS and drives one or more LCS operator consoles. Such a computer may also have a CAMAC-based data acquisition and control capacity. A typical LCS data acquisition front-end computer runs the VAXELN real-time kernel and handles hard real-time data acquisition through CAMAC. The VAXELN nodes do not have local disks.

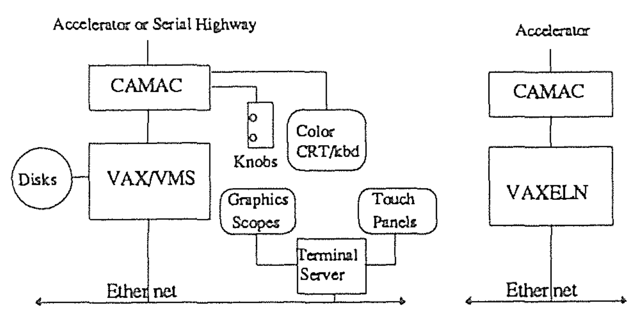

Figure 1. LAMPF Operator Interface and Front End Computers

Each LCS operator console is composed of one or more color character-cell CRTs which are shared between a number of application programs, several graphics scopes, trackball-based touch panels, and a set of analog control knobs. The graphics scopes and touch panels are attached to the computer

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Status Report on the Advanded Light Source Control System

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Abstract

This paper is a status report on the ADVANCED LIGHT SOURCE (ALS) control system. The current status, performance data, and future plans will be discussed. Manpower, scheduling, and costs issues are addressed.

I. Introduction

The ALS control system was designed around the concepts of parallel processing, high CPU and I/O bandwidth, and human-friendly interface. Figure 1 shows the system architecture and its five primary layers (for details of the system see References [1] and [2]). Layer 1, represented by the Intelligent Local Controllers (ILCs), interfaces to the accelerator hardware and communicates with Layer 2, the Collector Micro Module (CMM). Layer 3 is the Display Micro Modules (DMM) that has bus access to the CMM and in turn communicates with the operator stations (Layer 4) via serial links. The operator stations are high-performance Personal Computers that have Ethernet network (Layer 5) access to file servers and other network services.

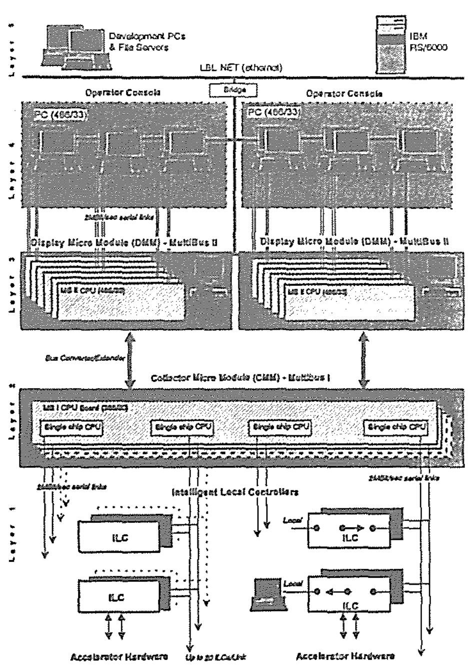

Figure 1. ALS control system architecture.

The ALS consists of an Electron Gun, a Linac, a Linac-to-Booster line, a Booster, a Booster-to-Storage-Ring line, a Storage Ring (SR), and a number of user beamlines. The control system is currently operating the existing parts of the ALS accelerator hardware consisting of the Gun, Linac, Linac-to-Booster line, and the Booster; the Booster-to-Storage-Ring line is being implemented now. The Storage Ring accelerator hardware is under construction; completion is expected sometime during the second quarter of 1992. We will then be ready to begin commissioning the SR via the control system, both locally and from the Control Room.

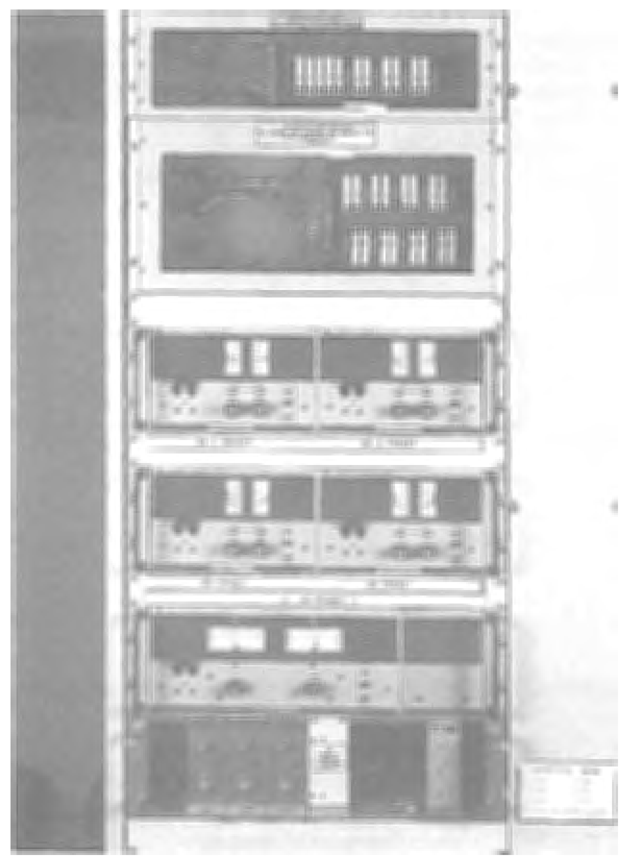

Figure 2. Typical ILC installation.

II. Layer 1 (Intelligent Local Controllers)

The ILC is an intelligent controller consisting of an 80C186 main processor, an 80C187 math co-processor, and an 80C152 serial-control processor sharing 64 Kbytes of battery backed

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LESSONS FROM THE SLC FOR FUTURE LC CONTROL SYSTEMS*

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The SLC control system is the dynamic result of a number of forces. The most obvious force is the functional requirements of the SLC itself, but other forces are history, budget, people, available technology, etc. The plan of this paper is to describe the critical functional requirements of the SLC which caused significant development of the control system. I have tried to focus on functional requirements as a driver, and I will describe some solutions which we have implemented to satisfy those requirements.

The important functional requirements drivers for the control system discussed in this paper are:

- ➪ Repetition rate
- ➪ Sensitivity to orbit distortion
- ➪ Stability/Automation
- ➪ Accelerator Development

REPETITION RATE

The SLC runs for physics production at 60 or 120 Hz. At 120 Hz, 5×10^{10} particles per bunch, 3 bunches/beam pulse, and 50 GeV, the average power is 150 kW. If the beam has a small enough cross sectional area, such a beam has caused damage to beam vacuum pipes, beam vacuum flanges, collimators, or other beam line components by heating. Such events occur because the beam has become "errant"; that is, it has wandered from its nominal orbit, and is actually striking the device. If this situation is not detected, then more and more energy is put into the device, as the SLC pulses keep coming. The first issue is to detect the event, and turn off the beam. There are a number of classic methods of such detection (ion chambers, beam current comparators, etc.), and the SLC uses them.

Once the event is detected, how does one fix the problem? Usually the answer is to steer or tune the machine. But now a situation, which appears as a form of "relaxation oscillator," happens. To tune the beam, one needs beam in the machine. But because the beam is mistuned, the machine protection system detects the same problem again and turns off the beam again. How does one break this impasse?

The first, and obvious answer is to tune at a lower beam intensity; instead of running with 5×10^{10} particles, tune with 2×10^{10}. This doesn't work in general. The SLC with 2×10^{10} particles is a sufficiently different machine from the SLC with 5×10^{10} particles that the problem often disappears at 2×10^{10}, only to reappear when the current is raised to 5×10^{10}.

The next answer is to tune at the same beam pulse intensity, but to lower the repetition rate. This is, in fact the technique that is used at the SLC. However, it does not work to simply lower the repetition rate of all components in the machine to 10 or even 1 Hz. Power is dissipated in the rf and pulsed magnet systems, and lowering the repetition rate in such components changes their characteristics. Therefore, an effective rate limiting strategy requires that the rate of running the pulsed components of the machine not be changed, but that only the injection of electrons and positrons be moved to the lower rate.

The above discussion is an overview of the simplest situation; and even it isn't really simple—how the creation and injection of positrons is handled is problematic even in this situation. More complicated scenarios are also possible in the SLC [1].

Another issue for the Machine Protection System is configuration flexibility. As the SLC configuration is changed during tuning or machine studies, the requirements on machine protection change. An obvious example is a repetition rate change from 60 to 120 Hz. A less obvious example is changing the place where the beam is stopped. It is a requirement of the machine protection system that it react to such configuration changes in as seamless a manner and as prompt as possible. At the SLC, this functionality is provided by means of the timing system, which includes distribution of timing "patterns" which allow pulse to pulse timing configuration changes. This functionality is being augmented because it is required by a project to upgrade our present Machine Protection System [2], and because it is needed for the next phase of our Fast Feedback system.

To summarize the functional requirements: The repetition rate for a linear collider can allow errant beam to damage or destroy beam line components. A protection scheme is required which detects such situations, which limits the beam, and which allows retuning of the machine to stop the situation. It is required that retuning be done at or near the beam conditions which cause the errant beam. In addition, the machine and its machine protection system must be easily and quickly reconfigurable.

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Process Control for The Vivitron : the generator test set-up

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Abstract

The VIVITRON is a 35 MV Van de Graaff tandem electrostatic accelerator under construction at the CRN since 1985. About half of the parameters are controlled by equipments which are highly stressed by their physical environment : sparks, electrostatic field, X-rays, vacuum, and gas pressure. It needs a dedicated process control system. The described control system is used since early 1991 to perform the voltage tests of the generator. It provides important information for the accelerator tuning and for the full size control under development.

I. THE VIVITRON

The Vivitron Van de Graaff tandem accelerator, under construction at the Centre de Recherches Nucléaires at Strasbourg France [1] is designed to reach a terminal voltage of 35 MV at its terminal electrode [2]. The tank (51 m long and 8.4 m in diameter) is filled with SF_6 at 8 bars. The charging system is a belt running close to the tube at a speed of 10 m/s. The column consists of a glass fibre / epoxy insulating assembly, supported by insulated epoxy posts. Seven porticos, large field-shaping shields, and discrete electrodes improve the electrical field homogeneity [6].

The expected energy will vary from 20 MeV/A for the light ions to 5 MeV/A for the heavy ions. The intensity should go from 10^{12} pps for the light ions to 10^9 pps for heavy ones.

II. THE FULL SIZE PROCESS CONTROL

A. Specific problems

The process parameters are spread over a large area. The control equipment, located at high voltage inside the accelerator tank and in the injector, are highly stressed by their physical environment : 35 MV breakdown flashes, 440 kJ stored energy, 1.7 to 10 MV/m electrostatic field, X-rays, vacuum, and SF6 gas pressure [3].

B. Architecture

A multi-level structure is implemented between the process and the operator.

Level 3 is in charge of the field equipment I/O interfaces, the handling, switching, buffering and communication of the I/O data. Some of these field equipment crates are located inside the accelerating tank and in the injector. They are connected to level 2 by optical-fibre links crossing the 2 MV/m electrical field. At least one crate is requested for each electrical equipotential level. The small space available in some "dead sections" imposes the choice of a small-scale bus crate.

Level 2 is located outside the vessel at ground level. It achieves communication with level 3 and with level 1 and provides data switching, concentration and handling.

Level 1 includes the communication interface, the real time control and the operator interface.

III. THE SET-UP FOR THE GENERATOR TESTS

For the generator tests, only a reduced process control is needed. No beam control is necessary, no automation is required, the number of parameters is limited and no equipment crate is needed inside the machine. All the information is fed out at both ends of the tank. Optical wires are used for sensors and activators at high voltage. Shielded and protected galvanic wires are used for those at the ground level. Thus, data acquisition, data switching and operator interface are dominant.

A. Current flow and terminal voltage

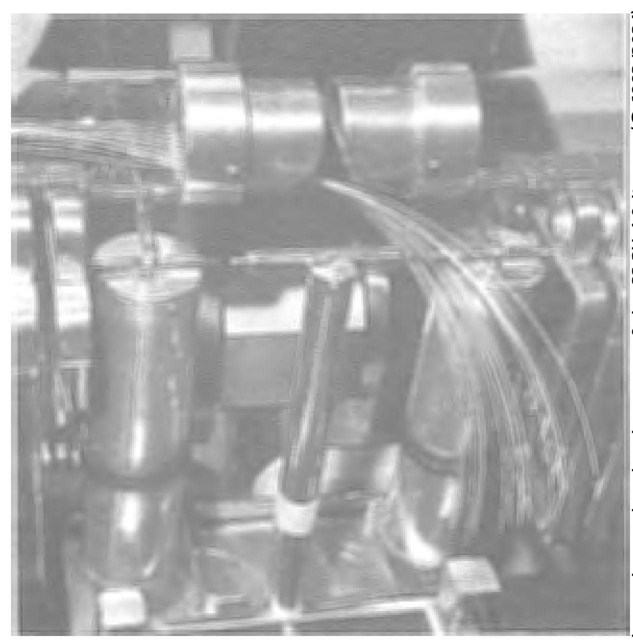

Figure 1. The current monitors in a dead section.

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High accuracy ADC and DAC systems for accelerator control applications.

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Abstract

In the work presented here the ways of construction, the apparatus for the precision measurements and control systems incorporated in the accelerating facilities of INP are considered. All the apparatus are developed and manufactured in the standard of CAMAC.

Introduction

While carrying the experiments on the precision measurements of the mezon masses on the installations with the electron - positron colliding beams one has to use the apparatus of a class 0.001% with the resolution about 0.0001%. An instability of the main power supply sources of magnetic systems of storage rings should not exceed 0.002%.

The powerful RF generators, the controlled sources of power supply with an output power of a few hundred kilowatts, pulse components of electron-optical channels, numerous digital devices including computers are the sources of different kinds of noises. Under these conditions, the stronger requirements on the noise damping are posed to the measuring and control equipment and to the analog data transfer lines.

In the power supply system of the facility VEPP-4 one has to measure of about two thousand points and to form the control signals for more than 500 channels. The time of energy rise is of a few tens of seconds. In the mode of operation one needs the high accuracy matching (0.1% - 0.01%) in the field variation in the magnetic components of accelerators. The technical parameters of the control and measuring structures should provide the operation of the power supply systems both in the static and in dynamic modes of operation.

Digital - to - analog converters

Usually, the power supply sources of the storage ring facilities requires the digital-to-analog converters (DAC) of quite a low fast action at an accuracy ranging from 0.1% up to 0.001%. Therefore, most of the converters used are designed on the base of the pulse width modulation PWM. The advantages of the given type of DAC are well known: the minimum of precise components at a practically arbitrary resolution, high linearity, easily achieved the galvanic isolation of the analog part and consequently, a low price.

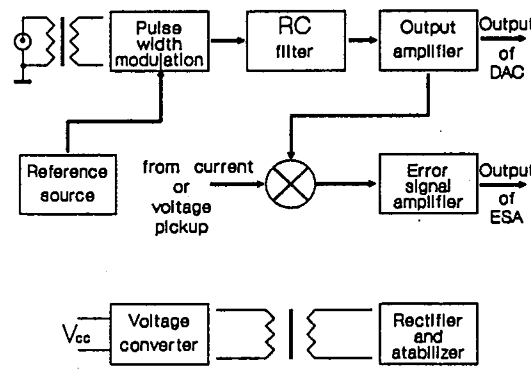

Fig.1. The analog section of PWM-DAC.

One of the popular developments of INP is an 8-channel code-to-duty factor converter (CDFC) located in the crate and transferring the control signal to DAC - PWM integrated directly to the control objects. The DAC signals in the form of different polarity pulse, the distance between carrying the data on reference voltage for control system are transferred through the coaxial cable with the transformer de-coupling to the distance of up to 500 m. The simplified schematic diagram of the converter is given in Fig.1. The pulsed signals from DAC arrive at the trigger controlled by the analog switches. The PWM modulated signal is filtered with the RC filter of the 3rd order. In order to match it with the control system the error signal amplifier (ESA) is envisaged which equalizer the DAC output signal to that from the current or voltage sensor. The galvanic de-coupling on power supply is performed with the help of high frequency converter with the transformer of special design with the minimum crossing capacitance. DAC parameters are: 16 bites, error - 0.01%, settling time - 0.4 s, temperature factor of the output voltage - 0.0003%/K. The given configuration is being widely used in the systems of pulse power supply of the transport channels for charged particles, in the power supply sources for the "high current" correctors, i.e. in those cases, where the controlled objects are distanced considerably and their groundings are

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The GSI Control System

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Abstract

The GSI accelerator facility consists of an old linac and two modern machines, a synchrotron and a storage ring. It is operated from one control room. Only three operators at a time have to keep it running with only little assistance from machine specialists in daytime. So the control tools must provide a high degree of abstraction and modeling to relieve the operators from details on the device level. The program structures to achieve this are described in this paper. A coarse overview of the control architecture is given.

I. THE GSI ACCELERATOR FACILITY

At GSI the heavy ion linac UNILAC runs successfully for 16 years. It produces beams of all elements up to uranium with energies between 1.4 and 20 MeV/u. In '89 the heavy ion synchrotron SIS and the experimental storage ring ESR started operation with ion energies up to 2 GeV/u.

A new control system has been designed for SIS and ESR which is adopted step by step also for the UNILAC.

The system has to handle quite different facilities,

— the UNILAC with 3 injectors and repetition rates of 25...100 Hz,
— the SIS with repetition rates of 0.1...3 Hz,
— the ESR with repetition rates of $\leq$0.001...0.1 Hz,
— transfer lines,

but has to provide an uniform operator access to all accelerators from one control room.

When the upgrading of the old components will be completed a total of 3000 devices scattered over an area of 250 × 250 meters have to be controlled. Complexity varies from simple DC magnets to ramped magnets (ramps generated from up to 900 samples) and diagnostic devices (up to 40kB of data). Fast switching of the machines allow time sharing between several experiments and injection to the next accelerator in sequence, all with independent beams.

II. OPERATING REQUIREMENTS

There is a need for several identical consoles for independent operation of accelerator segments and hardware redundancy.

A consistent "look and feel" has to be provided for the operator interface of all application programs.

To keep the control system serviceable and extensible it has to be a modular and uniform system with definite allocation of tasks. The size of the facilities suggests a decentralized, distributed and hierarchical system. Therefore real-time aspects are limited to the device handling level, data for these operations are stored there. By this means a clear separation between accelerator and device oriented aspects is achieved.

The operating level ("physics of accelerators"), located on powerful workstations, deals with the equipment as a whole and handles devices in a modeled form only. The device level ("physics of devices"), located mainly on microcomputers close to the devices, maintains and controls single devices. Both levels are connected by standardized device accesses using identical mechanisms for all devices.

III. CONTROLS COMPONENTS

On the operating level VAX 3100-VMS graphic workstations are installed forming a VAX cluster. Uniform software all over the system is ensured by cluster-disks. One to three VAXes are grouped as consoles for operator interaction.

The device level is equipped with two types of 68020 VME boards with a real time kernel. One is used as Master Processor (MP) for command evaluation. The other is equipped with an interchangeable communication interface and is used as Equipment Controller (EC) for device control and as Communication Processor (CP) for networking.

For communication between operating and device nodes ETHERNET is used. Devices are connected via modified MIL-STD-1553B serial bus with standardized InterFace Boards (IFB) as part of the devices. Besides this other interfacing like IEEE-488 is partly used by simply replacing the communication part of the EC boards. Typically 5 to 10 devices are driven by one EC.

Time signals for process synchronization are broadcasted from a central timing system to all ECs via serial bus (MIL-STD-1553B) and Timing InterFaces (TIF).

Each VME node is equipped with CP, MP, TIF and 1...9 ECs. A diagram of the components is shown in fig. 1.

Actually 33 operating computers are used in the main control room and in several local consoles close to experi-

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VME Applications to the Daresbury SRS Control System

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Abstract

The control system for the Daresbury SRS has recently been extended with a VME based alarm system which is operational. A further development is a steering system to provide servo control of the electron beam orbit position in the storage ring.

I. INTRODUCTION

The Daresbury SRS is a 2 Gev electron storage ring dedicated to providing synchrotron radiation to approximately 32 stations on 10 beamlines. It came into operation in mid 1981 and was upgraded with a high brightness lattice in 1987.

The control system for the SRS was designed and constructed in the period 1975-1980 and the original computers were upgraded in 1985.

The original control system provided an alarm condition monitoring system with a sampling resolution of 2 minutes. Recently, a dedicated VME system has been added which provides alarm monitoring and indication with sampling at the level of 5 seconds.

The high brightness lattice upgrade in 1987 reduced the source size by a factor of 10 and this led to difficulties with beam alignment and positional drift over the period of a stored beam. Work is under way to provide a VME based beam steering system to provide servo control of the electron beam position.

This paper will give a brief description of the SRS control system followed by a description of the new alarm system. A description of the beam steering system and its present status will be given.

II.THE SRS CONTROL SYSTEM

The SRS control system consists of a network of 4 Concurrent Computer Corporation(CCC) 3200 series computers as shown in Fig 1.

All computers in the network have a CAMAC system crate and communicate via CAMAC fast serial data links. CCC3230 is the operator interface computer providing service to three operator consoles in the main control room via a CAMAC parallel branch. Two of the operator consoles contain a colour display and keyboard (Tektronix 4207), a knob and tracker ball and a monochrome graphics display. The third console contains a Tektronix 4207 colour display and keyboard and serves as the personnel safety console.

CCC3205A and CCC3205B computers provide the interface to the plant via serial CAMAC highways. CCC3205A has two serial highways, one for the linear accelerator and Booster synchrotron and one for the Storage ring and Beamports. CCC3205B provides control for the beamlines with one serial CAMAC highway. Local control at the plant is implemented with Tandy 102 computers. The total parameter count presently stands at approximately 1800.

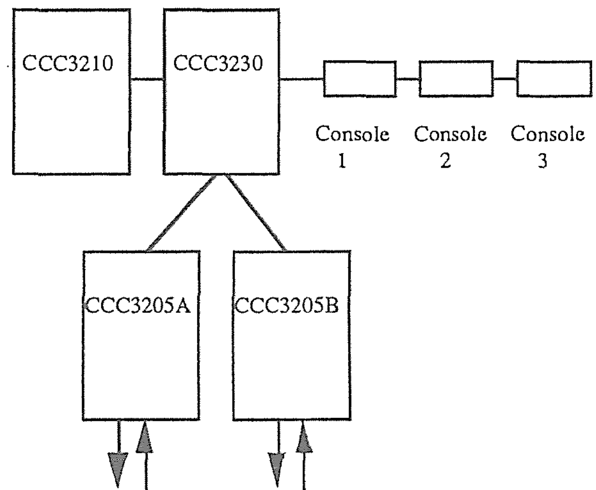

Fig 1. The SRS Control system

CCC3210 is offline to the control system and is used for programme development and testing.

High level programming is done in RTL/2 with more recent applications written in C.

III. THE ALARM SYSTEM

The original SRS alarm system was in operation for 9 years from the start up of the machine. Over this period, the system has been found to have several disadvantages:-

1. Noisy analogue input signals gave spurious alarm indication which led to alarms being ignored by operators.
2. Alarm conditions were applied to large numbers of parameters which led to 'swamping' of the alarm display and the operators being presented with more information than they could reasonably handle.
3. The large number of alarmed parameters led to difficulties in administration of the system.
4. The 2 minute sampling rate meant that the system was in fact no more than a fault indication system rather than a true alarm system.

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Accelerator Control Systems in China

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Abstract

Three accelerator facilities were built in the past few years, the 2.8 GeV electron positron collider BEPC, the heavy ion SSC cyclotron accelerator HIRFL and the 800 MeV synchrotron radiation storage ring HESYRL. Aimed at different research areas, they represent a new generation of accelerator in China.

This report describes the design philosophy, the structure, performance as well as future improvements of the control systems of the these facilities.

I. INTRODUCTION

The development and research of accelerators in China has made good progress in the past thirty years. Many low energy accelerators for research and application have been constructed, including high voltage type accelerator, cyclotron, linear accelerator, betatron etc. Their application covers a wide range: medical treatment, industrial irradiation, non-destructive inspection, isotope production and many other fields. The three newly completed high and medium energy accelerator facilities, Beijing electron positron collider(BEPC), Lanzhou heavy ion research facility(HIRFL) and Hefei synchrotron radiation source(HESYRL), aimed at different scientific research areas, represent a new generation of accelerator facilities.

Early accelerators are mostly controlled by panel meter and push button type manual control system. Application of microcomputers to accelerator control system started at the beginning of 80's when microcomputers were becoming popular in China.

This paper is not intended to be a general survey. Control systems of the three new accelerator facilities, which are relatively larger in scale and more complicate in structure, are described here with the emphasis on the system architecture.

II. BEPC CONTROL SYSTEM

BEPC is the first high energy accelerator built in China. The main facilities of BEPC are a 1.4 GeV electron linear accelerator injector, a 1.4 GeV beam transport line and a 2.8 GeV electron storage ring. The project was started in 1984 and completed in 1989.

Because of the strict time table for the BEPC project, the leaders of the project decided early in 1985 that in order to reduce development work and shorten the construction period the new control system of SPEAR ring should be adopted as the base for BEPC.

BEPC control system is a typical centralized control system. A VAX11/750 serves as the central control computer. Serial CAMAC systems are the base for equipment interfacing.

1. System Configuration

Fig. 1 is a block diagram of BEPC control system. The system is functionally divided into three levels.

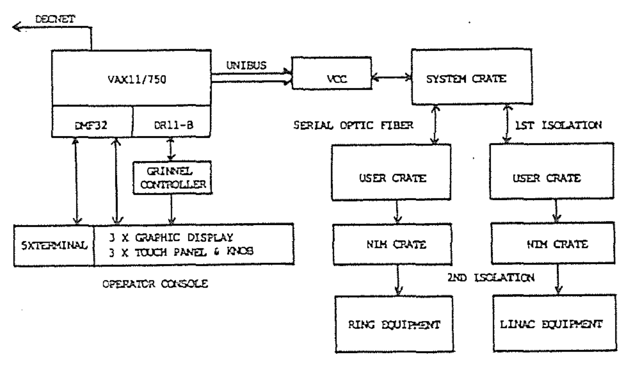

FIG.1 BLOCK DIAGRAM OF BEPC CONTROL SYSTEM

First, at the center of the system is the DEC VAX11/750 computer, which is equipped with a asynchronous serial interface board for connecting terminals and knobs, a DR11-B DMA interface for connecting color display monitors, and other standard peripherals such as hard disks, printers, tape drivers etc. A SLAC designed Vax CAMAC Channel(VCC) is the key element in data communication network. It is a DMA controller to interface VAX11/750 UNIBUS with CAMAC system. Two CAMAC system crates are controlled by the VCC, one for the linear accelerator the other for the storage ring. One system crate houses several serial branch driver modules and each branch driver starts a fiber optic serial high way loop which connects up to 7 user CAMAC crates. The second level is the local control stations formed by user crates. I/O functions are performed by the local control stations. Each local control substation controls one

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HESYRL Control System Status

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Abstract

HESYRL synchrotron radiation storage ring was completed in 1989 and has been in commissioning since then. Now it has met its design specification and is ready for synchrotron light experiments. Control system of the project was completed in 1989 and some modifications were made during commissioning. This paper describes its present configuration, status and upgrading plan.

I. INTRODUCTION

Hefei National Synchrotron Laboratory (HESYRL) is a dedicated synchrotron light source. It's main facilities are a 200 MeV electron linear accelerator, a beam transport line, an 800 MeV electron storage ring and the experiment stations.

Design and construction of the ring and linac control system started in Oct. 1984. The linac control system was completed in 1987 and the ring control system was completed in 1989. Modifications have been made to the system during two years of machine commissioning, including RF control, vacuum monitoring and new control programs.

The ring control system is a distributed computer control system consists of a PDP11/45 computer, two PCs, a communication microcomputer system(CMM) and up to 40 local control microcomputer systems(LCM).

The linac control is essentially a manual control system.

A timing system consisting of two microcomputers provides all necessary triggering signals for the linac and the injection system.

II. RING CONTROL SYSTEM

A. System Configuration

Fig.1 is a block diagram of the ring control system.

Two PCs perform the main control function. Console display and command input are also performed on the PCs. The PDP11/45 minicomputer system, originally planned to be employed as the main control computer, is now only a part of communication system because of its limited memory and poor display ability. The two PCs are connected to the DZ11 ports of the PDP. Ring control programs are executed on the PCs.

Storage ring and beam transport line equipments are controlled and monitored by local control micros. The LCMs are located near the equipments. Each LCM controls only one or one type of equipments.

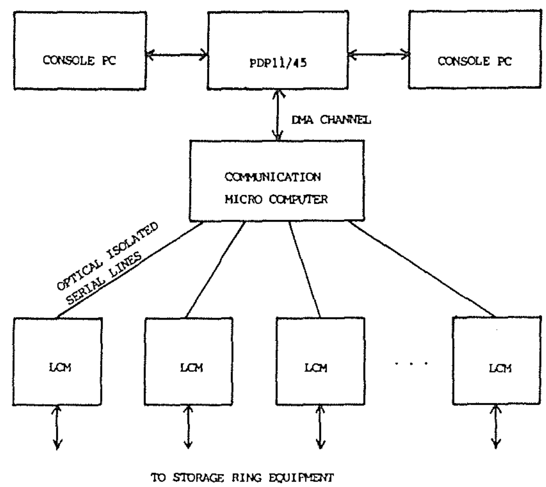

FIG. 1 BLOCK DIAGRAM OF HESYRL RING CONTROL SYSTEM

A LCM consists of a MULTIBUS crate, a SBC80/24 or SBC80/20-4 CPU board, a home designed serial interface and memory expansion board(HCOM) for communication and a few interface boards for equipment interfacing.

System communication is performed at two levels. The console PCs exchange data and commands with PDP through its serial lines. The PDP communicates with LCMs via a dedicated communication microcomputer system, which is a MULTIBUS system composed of a master SBC 80/24 CPU board, a DMA communication board and between 1 to 10 intelligent communication boards(COMM).

The COMM board is similar to Intel SBC544 intelligent asynchronous communication board. It has a Z80 CPU, 4 serial ports,on board RAM/ROM and dual port RAM memory which can be accessed by both a MULTIBUS master and the on board Z80. One COMM board can handle communication with 4 LCMs.

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The Control System of HIRFL

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1. Introduction

The Heavy Ion Research Facility in Lanzhou (HIRFL) is a multi–purpose and variable energy machine designed to accelerate wide range of ions. [1] In order to obtain a designed beam (particale and energy) and to transport it to a proper experimental areas in a short time, it requires to modify a great number of parameters, this cannot be easily achieved without the help of a computer.

The control system design and construction was started in 1983. First of all, some local control station of accelerator subsystems were finished in 1988 and satisfied the needs of operating and commissioning at the elementary level. Controlling the HIRFL process is implementing at a high level.

2. The brief description of control system

Fig.1 shows the general layout of the control system for HIRFL.[2] It is based on CAMAC distributed process configuration.[3]

(1) The local computer control stations are designed according to the accerlerator subsystems, such as Magnet, R.F, Vacuum, Injection and Extraction, Beam line etc. and were finished in 1988. They can meet the case of beam tuning and accelerator operating at elementary level.

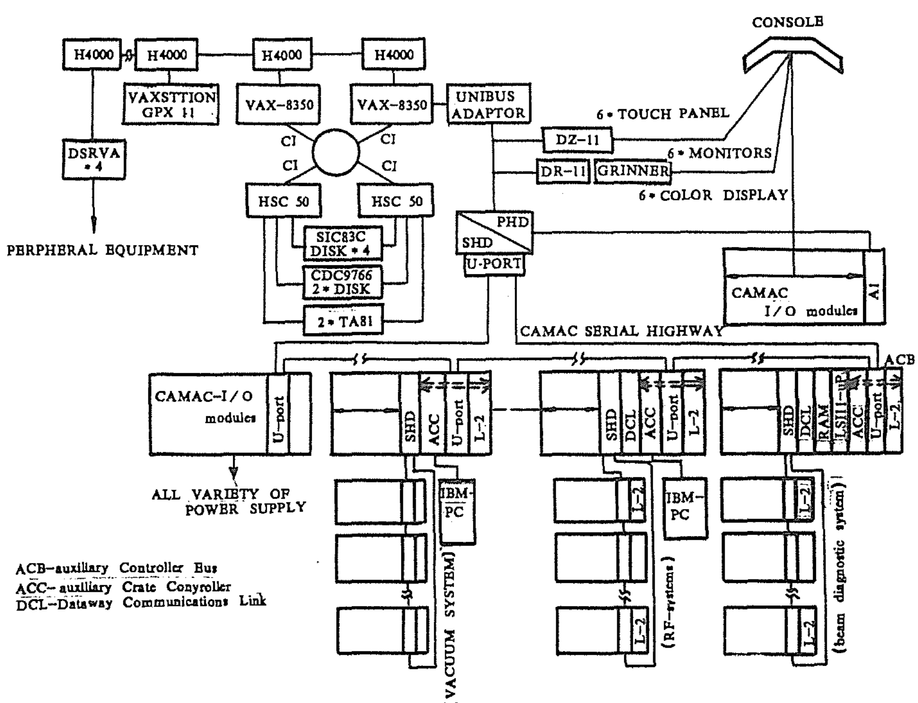

Fig.1 The block diagram of HIRFL control system

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Control System for a Heavy-Ion Accelerator Complex K4 – K10

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Abstract

Control systems for newly created accelerators, perhaps for the first time, may be designed almost only around international standards for communication and control techniques. This is also true for the project of a control system for the accelerator complex K4-K10 at the Joint Institute for Nuclear Research Dubna. Nevertheless, open systems architecture with construction principles being essential for modern systems of such big devices as particle accelerators leaves designers enough possibilities for solving even very sophisticated problems.

I. INTRODUCTION

The control system of the heavy-ion accelerator complex K4-K10 is similar to the systems developed for controlling the accelerators of other physical laboratories the experience of which was used in preparing the given project [1,2,3]. Nevertheless irrespective of the similarity of accelerators and control problems there are no equal control systems. This depends not only on the differences of accelerators as such but first of all on the time the system was designed and on the present state of computing and communication technique and on the special features of the system architecture, which allow new technical acquisitions during the realisation.

II. THE ARCHITECTURE OF THE K4-K10 CONTROL SYSTEM

The architecture of the K4-K10 control system is based on a two level distributed computing system (Fig. 1). The upper level uses a modular system IEEE 1296 (Multibus) from the Siemens AG [4] (SIMICRO) as well as workstations with UNIX and X Window in the Central Control Room, and is integrated into a system via a Local Area Network (IEEE 802.3).

The standard IEEE 1296 and its realisation in the SIMICRO products allows a high computing power inside every crate (the CPU on-board in the SC^{TM}-systems based on RISC processors providing 5 MIPS and more) as well as the use of CPU with embedded PC/AT 386 in the OSM^{TM} and AMS^{TM} systems[1]. These SIMICRO systems are equipped with a complete set of communication modules for LAN in the IEEE 802.XX standards.

The functions of the system at this level are supported by the operating system SORIX^{TM} - a UNIX^{TM} Real Time version (reaction time for interrupt signals ≤ 100 µsec.) and permit an exit to LAN via TCP/IP protocols[2].

Therefore, using the possibilities of the 7 level scheme for the OSI model of open systems, the architecture of the upper level of the control system provides an output to the equipment and to the real time programs as well as a complete support for the TCP/IP protocols for an output to a LAN IEEE 802.XX. According to the loading of the network at this level by means of bridges one may distinguish two LAN segments: one for the workstations WS in the Central Control Room running under UNIX and the other for the Front End Computing. The latter are mainly crates in the IEEE 1296 standard with Real Time UNIX, joining the node computers for data acquisition and handling in the control mode as well as that for graphics and monitoring. They are equipped with terminals, Touch Screens and other man-machine communication devices.

The lower level of the distributed computing system directly corresponding to the equipment and executing devices and based on standards for industrial systems (for example in the VEPP4 [5] CAMAC instrumentation is used at this level) is connected to the upper level by means of the communication environment FIELD BUS (MIL-1553-B). This standard mostly agrees with the demands for a multidrop bus and in 1983 was proposed as a standard protocol for the field bus in accelerator control systems [6]. Together with well developed hand shaking features for the message transfer between bus controllers and remote terminals (RT) this standard allows simple and cheap data transfer to single serving devices, fulfilling simplest functions. For connecting digital measuring devices to the upper level the standard IEEE 488.X is used.

For the most part all the bus controllers (BC) MIL-1553-B are placed on the upper level of the control system. They provide the interfacing of the node computing system to the lower level equipment. The BC for the K4-K10 control system is developed on the basis of a processor module in the Multibus II standard, designed in the Laboratory of Computing Technique and Automation of the JINR using the VLSI of a 32-bit microprocessor set K1839 software-compatible with a micro VAX [7]. The interface controller for the MIL-1553 bus is a piggy-back module for the CPU board. One such BC may control 30 standard interfaces (Remote Terminals) on each bus.

The standard interface of the MIL-1553 bus has to provide a prompt/reply regime. In this case a microprocessor is needed. In the case of simple messages of the type "adjust and/or read" it has to handle the transfer directly.

The use of the MIL-1553 for the communication with the equipment together with the time synchronization channel allows one to put the real time mode on the lowest control level. Such a solution proposed and realized in the GSI [1] relieves the upper control level of the real time business and allows on this level the use of the LAN 802.3 alone without a TOKEN RING (IEEE802.5) as it is done for the SPS/LEP in CERN [2].

1TM SIMICRO, SX, SORIX, OSM, ASM - Trade Marks of SIEMENS AG
2TM UNIX - Trade Mark of AT & T

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Future Directions in Controlling the LAMPF-PSR Accelerator Complex at Los Alamos National Laboratory*

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Abstract

Four interrelated projects are underway whose purpose is to migrate the LAMPF-PSR Accelerator Complex control systems to a system with a common set of hardware and software components. Project goals address problems in performance, maintenance and growth potential. Front-end hardware, operator interface hardware and software, computer systems, network systems and data system software are being simultaneously upgraded as part of these efforts. The efforts are being coordinated to provide for a smooth and timely migration to a client-server model-based data acquisition and control system. An increased use of distributed intelligence at both the front-end and the operator interface is a key element of the projects.*

I. INTRODUCTION

The integration of the Los Alamos Meson Physics Facility (LAMPF) and the Proton Storage Ring (PSR) control systems is presenting a series of problems for the operations and support personnel using the two systems. The two systems were developed independently using different personnel, different underlying philosophies and different equipment but developed interdependency when the operating and support groups were combined in 1988. A detailed discussion of the current control systems is presented in a companion paper in these proceedings.

II. PROBLEMS AND IMPACT

A. LAMPF RICE System

The LAMPF Control System (LCS) was built upon the LAMPF-designed Remote Instrumentation and Control Equipment (RICE) System. RICE is the hardware and software interface between the actual accelerator devices, such as magnets and beam-line instrumentation, and the software that operators and developers use to control beams.This system is illustrated in Figure 1. RICE presently utilizes 73 of 80 possible modules handling 10,000 data and control points distributed along approximately 2 km of beam channels.

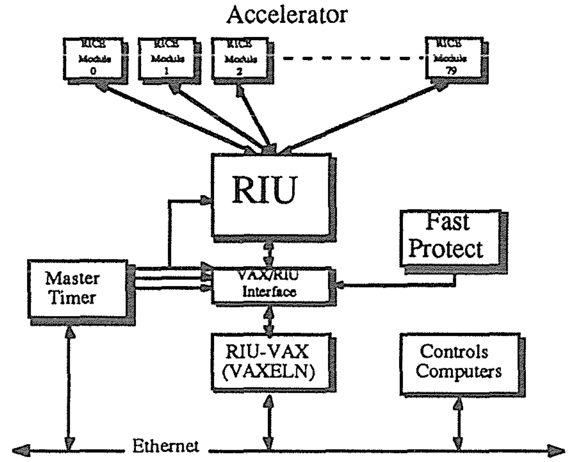

Figure 1. The LAMPF RICE System.

The RICE system has several limitations. First, RICE allows only one timed data request per beam pulse. At the low repetition rates characteristic of tuning beams, this feature can cause requests for device readout to become deeply queued and can cause tuning mistakes as operators react to "old" data. Second, the RICE star architecture places limits on the maximum data rates. Third, the RICE system is fairly rigid. For example, the current implementation of the linac harp system permits data from only two harps at any time and requires availability of greater than 50% of the RICE system to obtain that data. Fourth, there is a need for higher accuracy and precision than is available with RICE. Finally, it is estimated that 30% of the parts in the RICE system are no longer commercially available.

B. PSR ISS System

The PSR Control System is based upon a series of PDP-11 computers known as Instrumentation Sub-Systems (ISSes) which communicate with a central VAX system using serial CAMAC [1]. This is illustrated in Figure 2.

* Work supported by the US Department of Energy

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Common Control System for the CERN accelerators

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Abstract

The PS and SPS Accelerator Control Systems are becoming obsolete and need urgent rejuvenation. After a control users forum, where users expressed their needs, two main Working Groups were set up, consisting of Control and Equipment Specialists and experienced Machine Operators. One Working Group studied the architecture and the front-end processing and the other a common approach to the application software needed to run the CERN accelerator complex. The paper presents the technical conclusions of their work and the policy to implement it, taking into account the necessity to operate both machines without interruption of the Physics Program.

I. INTRODUCTION

The complex of CERN accelerators is divided in two sets of different characteristics. The PS set is constituted of ten different accelerators which represent the source of all particles accelerated in CERN (maintained by PS division); they are small and mainly fast cycling machines. The SL set is composed of two bigger machines, the SPS and LEP which are slow cycling accelerator or particles colliders (maintained by SL division). The two sets are, broadly speaking, separated by the Swiss-French frontier.

The PS and SPS accelerators control systems were conceived and implemented some 15 years ago. They are based on 16 bit computers, with a proprietary operating system and a star network. These components do not permit the use of modern industrial software packages and communication standards. Their maintenance is expensive and is becoming more and more difficult. The consolidation of the control systems has become necessary and urgent, and it was felt that one should profit from this consolidation to aim at a real convergence of CERN's accelerator control systems.

In order to work out a common technical solution, the collaboration between the PS and SL control groups has been reinforced considerably since the beginning of the year 1990. A common consolidation project is the result of this collaboration and it was elaborated by working groups of the two divisions. Joint working groups were set up to study the different aspects of the project and to reach the necessary consensus on what should be done. [1]

The first working group designed the common control system architecture, the front end processing and discussed the network characteristics, the local control facilities and the interface between the controls and equipment groups.

The second working group defined a common approach to the application software needed to run the accelerators, discussed the programming environment and the possible software tools and studied the future layout of the work place in the control rooms.

Other groups, linked with the two previous ones, worked on specific subjects like the Equipment Control Protocols, the common on-line data base, the Man Machine Interface, the Timing and Synchronization problems. They generally worked out common solutions which are today in the implementation phase.

II. ARCHITECTURE

The new Common Control System consists of three layers: Figure 1

- the control room layer with its consoles and central servers;
- the front end computing layer distributed around the accelerators;
- the equipment control layer with the Equipment Control Assembly (ECA) crates which form part of the equipment.

The hardware and software used on each level reflect the considerable variety of accelerator components to be controlled. The new architecture offers more flexibility and will allow continuous partial upgrading as technology evolves.

A. Control Room Layer

It must fulfil two main functions:

- Provide the operators with a reliable, user-friendly interface to the accelerators. Modern workstations running the commercial software package X - windows with a suitable commercial tool kit to construct the user interface were chosen. The operator work places are very demanding in terms of graphic and interaction facilities. The key point in selecting the new platforms is the interoperability with the existing equipment and the portability of the software between them. We hope the choices made, UNIX operating system (OSF based in the future) with X-Window and Motif tool kit and communication by the TCP/IP protocol, will allow a smooth transition from one generation of hardware to another.
- Offer a number of central services through servers (which are generally more powerful machines of the same family as the workstations). These central services can be the coordination of various control tasks, central data and file storage, model computing and collection of alarms.

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New Control Architecture for the SPS Accelerator at CERN

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Abstract

The Control System for the 450 Gev proton accelerator SPS at CERN was conceived and implemented some 18 years ago. The 16 Bit minicomputers with their proprietary operating system and interconnection with a dedicated network do not permit the use of modern workstations, international communication standards and industrial software packages. The upgrading of the system has therefore become necessary.

After a short review of the history and the current state of the SPS control system, the paper describes how CERN's new control architecture, which will be common to all accelerators, will be realized at the SPS. The migration path ensuring a smooth transition to the final system is outlined. Once the SPS upgrade is complete and following some enhancements to the LEP control system, the operator in the SPS/LEP control center will be working in a single uniform control environment.

I. HISTORIC REVIEW

The SPS control system was designed in 1972 and brought into operation in June 1976. By that time no standard communication network protocol existed and pioneering work had to be done to interconnect initially some twenty minicomputers located in 6 equidistant equipment buildings and one central control room around the 7 Km circumference of the SPS accelerator ring. The minicomputers used were NORD10 from Norsk Data with 16 KByte core memory and 128 KByte drum mass storage. The equipment interface consisted of CAMAC crates connected to the computer's I/O bus with CAMAC modules linked directly to some of the beam instrumentation while all other equipment was controlled via a CERN designed multiplex (MPX) system composed of a serial field bus, MPX crates and user dedicated MPX modules.

On the software side, the manufacturer's operating system has been modified to suit the particular real-time control requirements of our distributed multiprocessor environment. While most of the software drivers were written in computer assembly code, an interpreter, called NODAL, has been developed to provide easy interaction between the operator and the equipment connected to CAMAC, remote access facilities and network functions. Every computer had a resident NODAL interpreter allowing to use it in interactive mode and in stand alone operation for test and commissioning purposes. No one computer would be the over-all master of the control system and the message transfer system was designed so that any computer could pass a message to any other without a preset master-slave relationship, implying that the system was completely symmetrical and transparent [1].

II. PRESENT SITUATION

Since the start-up of the SPS in 1976, the control system has been extended to cope with the changing requirements of the accelerator which was initially designed as a pulsed proton accelerator for fixed target experiments, then modified to act as a proton/antiproton storage ring for collider physics, and now also as an injector to LEP, accelerating electrons and positrons interleaved with proton acceleration. Such evolution has required a great flexibility of the control system with the ability to modify programs as necessary in a simple way and to add computers, network links and equipment interfaces where and when required, sometimes even during the exploitation of the accelerator complex.

Today the SPS control system is composed of 52 operational process and central computers (NORD100) interconnected by a multi-star network with 6 Message Handling Computers (MHC). The interfacing between computers and accelerator equipment is done by CAMAC (72 crates and 450 modules) and by the MPX system (693 crates and 5500 modules). Figure 1.

With the need to operate the SPS in a supercycle mode when using it as a LEP injector, major additions had to be made to the control system since about 1986. A more flexible and versatile exploitation of many accelerator components like beam monitors and pulsed power converters was required. At the equipment level, this requirement has led to the use of 8 Bit and 16 Bit microprocessor based systems, embedded in G64bus and VMEbus crates. These Equipment Control Assemblies (ECAs) are connected to the appropriate NORD100 process computer via 1553 field bus segments and a VMEbus crate housing the bus controllers and linked to the computer's I/O bus.

In the accelerator control room, Apollo workstations where installed to cope with the more complex supercycle operation. These communicate with each other and with an

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The Next Generation Control System of GANIL

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Abstract

The existing computer control system of GANIL is being renewed to fulfil the increasing requirements of the accelerator operation. This medium term major improvement is aiming at providing the physicists with a wider range of ion beams of higher quality under more flexible and reliable conditions.

This paper gives a short description of the new control system envisioned. It consists of a three layer distributed architecture federating a VAX6000-410/VMS host computer, a real time control system made up of a dual host VAX3800 and workstation based operator consoles, and at the frontend segment: VME and CAMAC processors running under the VAXELN operating system, and programmable logic controllers for local controls.

The basic issues with regard to architecture, human interface, information management, ... are discussed. Lastly, first implementations and operation results are presented.

I. INTRODUCTION

The GANIL laboratory has been operating since 1983 an accelerator complex consisting of three machines in cascade : a compact injector cyclotron and two fourfold separated sector cyclotrons (Fig. 1).

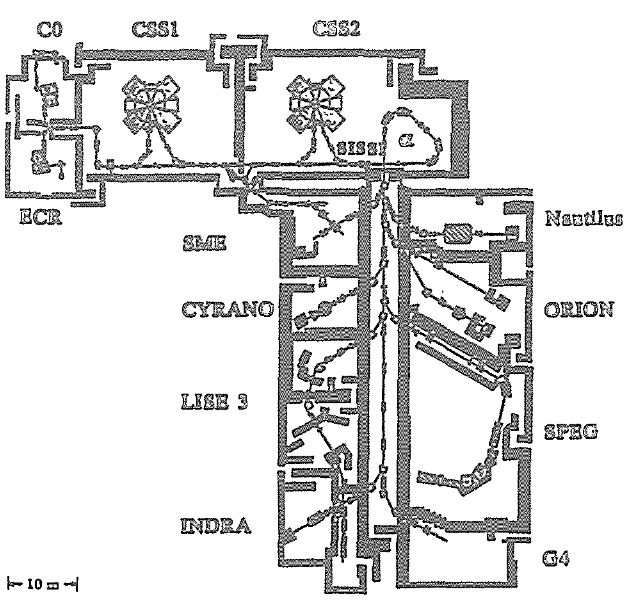

Figure 1. Accelerator and Experimental Areas

This facility provides the experimenters with fast heavy ion beams for fundamental research in the fields of nuclear physics, atomic physics and solid state physics, as well as for industrial applications.

Significant upgrades were carried out these last few years to augment the energy of heaviest ion beams and to increase their intensities by making use of new ECR source. Acceleration at GANIL henceforth encompasses ion species, from carbon to uranium, with beam energy ranging from up to 95 MeV per nucleon for the ions with masses up to 40 u to 24 MeV per nucleon for the heaviest ions.

The rejuvenation of the GANIL computer control system is under way, aiming at two main goals : 1/supersedes the present control system which is technologically outmoded and driven to its ultimate capabilities, 2/matches the performances of the emerging control system with the widening scope of the services in a large variety of domains (beam setting and tuning, surveillance, diagnostics, expertise,...) within an operator friendly environment.

This paper emphasizes the main topics to be considered when designing and implementing our next generation control system. In particular, stress is laid on using : 1/acknowleged industry or international open standard hardware and software products to achieve minimization of investment over the life of the system, 2/modular structures to make easier future expansions.

II. ACCELERATOR CONTROL SYSTEM

II.1. General Layout

The first generation control system adopted a centralized architecture built with a 16bit minicomputer (MITRA 625) which ruled over other kinds of processors devoted to local or ancillary tasks : 8bit (JCAM10/INTEL 8080) and 16bit (DIVA/MC68K) microprocessor CAMAC controllers, programmable logic controllers (APS30-12 and PB400). These processors are connected to the MITRA via two bit-serial 2.5 MHz CAMAC loops which bind up 40 crates with about 800 attached modules.

This tight coupling with the computer MITRA considering architecture and non portable software makes the control system vulnerable with regard to collapse, obsolescence and ageing of that computer.

In contrast, the GANIL control system to come is based on a distributed architecture. Intelligence is therefore handed over to local processors which are responsible for dedicated field operations. The chosen topology features three functional levels which intercommunicate by means of an Ethernet local area network (LAN) :

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REPLACEMENT OF THE ISIS CONTROL SYSTEM

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Abstract

In operation since 1985, ISIS is the world's most powerful pulsed spallation neutron source. The decision has been taken to replace the existing ISIS control system, which has been in use for over ten years. The problems of such a project, given the legacy of processor specific hardware and software are discussed, along with the problems associated with incorporating existing interface hardware into any new system. Present progress using commercial workstation based control software is presented with, an assessment of the benefits and pitfalls of such an approach.

I. INTRODUCTION

ISIS is based on an 800MeV proton synchrotron, running at 50Hz, providing an average beam current of 120μA onto a Uranium target. The injector, synchrotron, extracted proton beam line and target station have been under control of the present system both during commissioning (1980-85) and operation. Work is in progress to attain the design current of 200μA within two years.

The control system (old CERN-SPS pattern), is based on 5 GEC computers, assembly language Data Modules, a general purpose multiplex system for equipment interfacing (MPX) , CAMAC based operator interfaces (see Fig. 1) and an interpretive control language. There are approximately 15000 lines of data module source code. The equipment interface consists of 700 modules in 70 crates. There are several hundred control programs in use.

The present control computers are very modest in power and are very limited in storage capacity. The operating system allows us to control hardware from a number of concurrent interpreter processes on each processor. High priority processes communicating with hardware completely lock out all others. Communication with other systems is non-existent, peripherals such as floppy disks are obsolete and unsupported, backups require shutting down the control system and maintenance is expensive (24hr cover is essential). The various branches of the interface hardware are tied explicitly to particular processors– reconfiguring after a processor failure is impossible– a serious disk drive fault can, and has, shut down the accelerator for a few hours. An average ISIS experiment lasts two days, within which several data taking runs, all of which are essential, must be performed. These sorts of breakdowns, although infrequent, are highly undesirable.

The new system is required to take over all the current functions of the existing control (at least as well) and have the capability for much increased data storage, greater reliability, easy reconfiguration and extension and almost transparent communications with other computer systems.

The available effort is about 25% of that when the original system was created, when both decreases in staff and the load of supporting the existing system are taken into account.

II. PROJECT PLAN

The system currently being developed is based on the Vista Controls[1] software suite, and the Hytec Electronics[2] Ethernet CAMAC Crate Controller (ECC). The new software provides a fully distributed database driven control system with a graphical interface over a number of DECnet nodes (currently VMS only although work is in hand on a POSIX-compliant version). Each control or monitoring object is referred to as a *channel* and, by using the *channel name*, control screens can be generated with an interactive draw package. Our current development system is based on two DEC VAXstation 3100 colour workstations and two DEC VT1300 X-terminals, although it is not clear that the choice of processors is optimal. Figure 2 shows a general arrangement of the proposed new system, based on Ethernet (an alternative transmission medium would be FDDI).

The use of channel names, database and handlers (equipment routines) maps very well on to our existing system based on Data Modules. The graphical interface provided with the new software should enable the functions of 75% of the control software to be replaced without recourse to writing code.

The system-wide nature of the databases and the networked nature of the CAMAC driver crates makes access to all equipment possible from any processor– something which was not previously possible.

Terminals with any level of access to the control system can easily be added anywhere on site (if desirable!). A con-

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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.

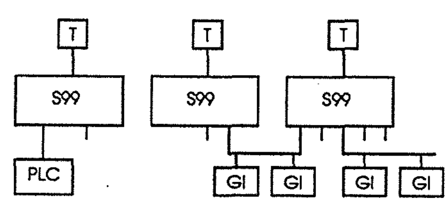

Figure 1. The main control system of the cyclotron.
T - terminal
PLC - Programmable Logic Controller
GI - General Interface (front-end controller)

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

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Upgrading the BEPC Control System

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Abstract

The BEPC control system has been put into operation and operated normally since the end of 1987. Three years's experience shows this system can satisfy basically the operation requirements, also exhibits some disadvantages araised from the original centralized system architecture based on the VAX-VCC-CAMAC, such as slow response, bottle neck of VCC, less CPU power for control etc.. This paper describes the method and procedure for upgrading the BEPC control system which will be based on DECnet and DEC-WS, and thus intend to upgrade the control system architecture from the centralized to the distributed and improve the integral system performance.

1. The system status and its milestone

The project of BEPC control system was determined to adopt basically from the SPEAR control system in january of 1985. The prototype control system was constructed during half year begun from september of 1985 at SLAC. In the end of 1987, the control system realized the on-line control and monitoring for the most equipments of BEPC Storage Ring (SR) and its Transport Line (TL), and was put into precommissioning at this time. The beam orbit correction has been brought into commissioning in june of 1989. The RF on-line control (including its ramp) was completed in march of 1990. Thus all the equipments of SR and TL were controlled by the computer, and the VAX-11/750 computer (the central control computer) becames a member of DECnet of IHEP at the same time.

From the operation experiences in the past several years, it seems that the philosophy and criterion for constructing the BEPC control system are available, which resulted that this system can be completed just on time schedule and have a high reliability of system operation.

2. Several problems in system

The BEPC control system architecture follows the old centralized control model of the SPEAR, we had done incessantly some improving work on system level in the past years, but still there are several problems which can't be solved. These problems are as follow:

1. The unique VAX-11/750 computer is used for the central control computer, its poor CPU power (only the 60 percent performance of VAX-11/780) limits the processing speed of whole control system; Many batch jobs (about 16 control processes) always reside in the memory, morever which heavily increases the load of VAX-11/750 computer system. These causes slow the response and processing speed of the entire system.

2. Due to we adopt the VAX-VCC-CAMAC (VCC, that is, VAX CAMAC Channel) hardware system architecture, one VAX QIO in CXCAMAC program takes 20 ms at least, so the VCC forms the bottle-neck of the control system communication. Especially it is obvious during the power supply ramping, the other jobs can not be serviced quickly.

3. The current human-machine interface is supported by two graphic colour monitors (resolution 512 × 512), two touch-screen with several computerized knobs. Now one monitor is occupied by one picture once a time, if we want to see several pictures of the different requirements of accelerator commissioning simultaneously, it needs to add more graphic display.

4. A fatal failure of the VAX-11/750 computer in the night (no on call service for computer) will break down the collider's operation. So a backup computer is needed to be considered.

3. System upgrade

After we analyzed the present conditions, we decided to reform the control system from the current centralized system to the distributed system and intend to solve those problems for improving the whole system performace.

a. The distributed control system architecture

In order to reduce the heavy load of VAX-11/750 and increase the speed of whole system responses, we divide the current control jobs on VAX-11/750 to several parts and load them into different computer nodes. the upgrade system will be based on the DECnet, its system architec-

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The rejuvenation of TRISTAN control system

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abstract

The current TRISTAN accelerator control system uses CAMAC as a front end electronics, and they are controlled by twenty five Hitachi minicomputer HIDIC 80's which are linked with an N-to-N token ring network. After five years from now, these computers must be replaced. This is because of the life time of control system and we have to cope with the requirements imposed by our future project such as the KEK B-Factory and the main ring photon factory projects. The rejuvenation of this control has to be done under some constraints such as the lack of manpower, limited time and financing. First we review the problems of current control system, then the philosophy of the new generation control system is presented. Finally it is discussed how to move to the new generation control system from the current TRISTAN control system.

1.Introduction

Eight years have passed since the current control system started the operation of TRISTAN accelerator [1] [2]. We have a few weeks hardware maintenance for every six month to keep our system highly reliable. The Hitachi company takes care of these maintenance; they clean up each computer, check its operation and replace some parts such as fans, filters, etc. The disk of each computer is replaced every five years. Hitachi also supports 24 hour "on call shift" for any computers troubles. Supported by these maintenances, the current system has been working very stable for these eight years.

Recently some of the I/O devices become out of date, and it becomes difficult to repair these devices. In addition to the problem, the current system can not satisfy the increased requirement of accelerator control. The latter is mainly caused by the lack of CPU power and by the fact that the process computers are all 16-bit machine. And the network transfer capability is limited by the lack of CPU power. In order to solve these problems, it is about a time to start thinking about rejuvenation of TRISTAN control system.

2.The TRISTAN complex and its control system

The accelerator complex of TRISTAN consists of three major accelerators. A 400 m electron linac accelerates electrons and positrons up to 2.5 GeV and injects into the accumulation ring. The accumulation ring accelerates them up to 8 GeV and injects them to the main ring. The main ring is an electron-positron collider . Two electron bunches and two positron bunches are circulating in the opposite direction and collide with each other at the mid-points of four straight sections. The current experiment runs at the center of mass energy of 29 GeV [3].

There are two independent control systems for their operation, one of the system takes care of the operation of linear accelerator and the other takes care of that of the accumulation ring and the main ring. This paper discusses about the rejuvenation of the later system [2].

The TRISTAN accelerator control system uses twenty-five minicomputers and two large general-purpose computers (The main frame: Hitachi HITAC and Fujitsu FACOM) [4].

The minicomputers control hardware equipment and serve for man-machine communication. The general purpose computers are used for the calculation of closed orbit distortion correction which overload the minicomputers. The 25 distributed minicomputers, Hitachi HIDIC 80's, are connected by optical fiber cables to form a 10 Mbps N-to-N token-ring network. From each minicomputer, a CAMAC serial highway is extended to the hardware equipment.

The minicomputers are classified into two groups: the system computers and the device-control computers. The system computers control six operational consoles and two alarm-processing. The device-control computes are three minicomputers for RF cavities control, five for magnets control, two for vacuum controls, two for beam monitor, two for beam transportation, one for timing control, one for program development, one for a gate way between the control system and main frame and one for general purpose.

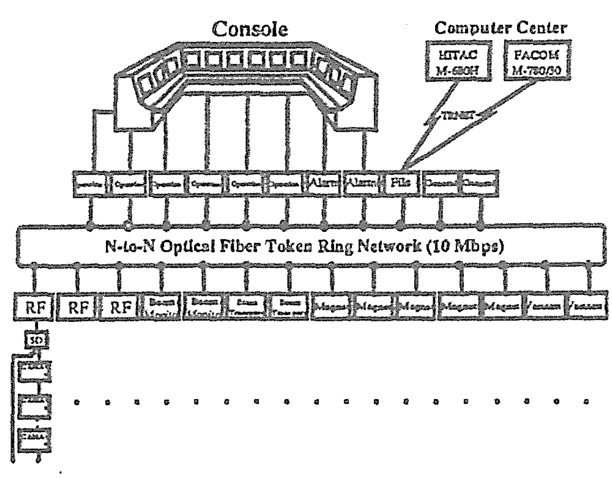

Fig 1: The current TRISTAN accelerator control system

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Upgrade Plan for the Control System of the KEK e−/e+ Linac

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Abstract

The KEK 2.5-GeV linac has been operating since 1982. However, in order to maintain reliable operation, the control system should be upgraded within a few years. We plan to replace the minicomputers and the main network connecting them. Thus, the architecture of the control software will also be revised. In the new system we should adopt software and hardware standards.

In the next control system we will employ the TCP/IP (DARPA) protocol suite for the main network and Unix workstations to replace the minicomputers. For connections to the local controllers, VME bus (IEEE 1014) will be utilized.

I. Introduction

The KEK 2.5-GeV linac provides electron and positron beams for both the TRISTAN collider and the Photon Factory storage ring. The linac control system was designed in 1979 and has been successfully operating since its commissioning in 1982. This old system is based on a distributed processor network, comprising eight minicomputers and hundreds of microcomputers, and on a control message exchange. Detailed descriptions have been given elsewhere [1] [2].

We have recently had many requests for increased functionality of the control system not included in the original design. However system resources were inadequate to implement the desired functionality. Furthermore, the minicomputers and the associated main network used in the old system will become unsupported by the computer company in a couple of years. We had thus decided to replace the main part of the control system and have carried out studies regarding the new system.

As a result, we have decided to adapt international and de facto standards as much as possible. The recent advances in electronic technology enable us to use common standards among various fundamental components. We have employed these standards in the new network system and computers. For the main network the TCP/IP (DARPA) protocol suite on the Ethernet (IEEE 802.3) media is utilized. Unix operating systems on a group of workstations and VME-bus-based (IEEE 1014) computers were chosen for the main console stations and subcontrol stations, respectively.

We describe below the design, current status and future of the new linac control system.

II. System Components

A modern control system must interlink many kinds of objects and facilities. We may link it with advanced technology, such as A.I. systems [3] or CASE tools. We may also link to the control systems of other accelerators or utilities, although some access limitation mechanism is needed. We may further link the new control system at the next upgrade time. Since the accelerators for research projects are always improving, we must combine many kinds of components to the control system. Thus we must make the control system as flexible as possible.

In order to fulfill the requests we cannot rely on only one hardware and software vender. We had better utilize international and de facto standards. If we have much capacity to develop control components, we may define our own standards. However, this would lead some difficulties in future, as we have already experienced. We thus want to utilize currently available standards.

The lifetime of an accelerator control system is relatively short, since electronics technology makes rapid progress and demands for control systems are changeable. We must thus always worry about future changes and upgrades of the control system. Since new technology and future standards are very likely to support existing standards, employing standards is promising.

A desire for standards has grown among both users and vendors recently. If we adopt standards, (a) since there will exist less ambiguity in the rules, we can develop reliable technology based on it, (b) since the required components may be obtained commercially, the development period may be substantially reduced, (c) since the standards in other fields may support each other, it may be easier to construct the entire system. These facts are especially important in a small system, such as in our case where manpower is limited.

A. TCP/IP Network.

Since equipment used for a accelerator is spread over a long distance, we must use some kind of computer networks between controllers. Since our linac is a pulsed high-power RF machine, in the old system we attached importance to noise elimination and have used proprietary fiber optic networks (Loop-1). Since their hardware and software are dedicated to the old system, we cannot utilize them for any other configurations.

Thus, we had to think about introducing a more standardized network, which can be adopted to various configurations. In order to be independent from suppliers TCP/IP protocol suite (DARPA) is most appropriate. We

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The New Control System for TARN-2

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The new control system for the cooler-synchrotron, TARN-2, is described. The new control system consists of OPU's (work stations) and EXU (control computer) linked with the local area network. The text message is used to transfer the control commands and their results. The control program CSA90 at EXU decodes the text message and executes it with the aid of the interface and periodic control subroutines. Both subroutines use common sharable image composed of the status, values, parameters and so on. The CAMAC, GPIB and RS232C are standard interface at EXU.

Introduction

A heavy-ion synchrotron-cooler ring, TARN2 has been constructed at the Institute for Nuclear Study, University of Tokyo. It has a maximum magnetic rigidity of 6.2 Tm, corresponding to 1.1 GeV for protons and 0.37 GeV/u for ions of charge-to-mass ratio 1/2. Now the injector is a sector-focusing cyclotron with K=68. The aims of TARN2 are to study the acceleration, cooling and extraction of heavy ions and so on. Recently study of the weak beam monitoring and experiment of atomic physics is being continued. So the TARN2 control system must gives reliable control functions and monitoring required to direct the up-to-date complex operations associated with on site experiment.

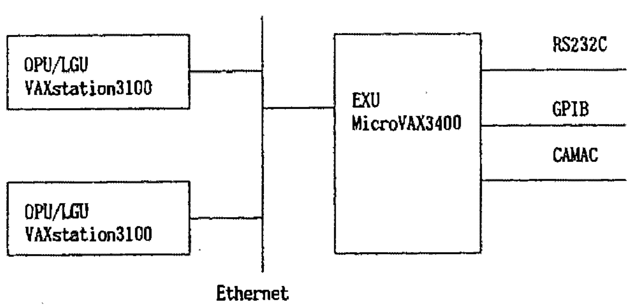

Fig.1 The new computer control system of TARN2

The present control system consists of the serial CAMAC, GPIB and microcomputers[1]. The serial CAMAC system covers static control system such as beam transport[2], injection, electron cooling[3] and a beam extraction system. On the other hand, dynamic control of both the RF acceleration and ring magnet system[4], is also performed with the dedicated microcomputers with external memory modules[5]. These systems well regulate TARN2 and now used without some troubles.

In 1990, basic design of the new computer control system was started and was authorized to combine the present I/O controllers. The present paper describes the new control system of TARN2 during the development phase.

Basic Architecture

In the new control system, the actual device control and man-machine communication is made by the separate units. The new system comprises OPU's (workstations) and EXU (control computer) linked with the local area network. The new computer control system of TARN2 is shown in Fig. 1.

The several kinds of workstations and PC's are used as OPU's. One is a VAXstation 3100. Another one is a microcomputer NEC-PC9801 with Ethernet board and DECnet-DOS. The uVAX 3400 is used as EXU and CAMAC, GPIB and RS232c are also available in the EXU.

The OPU and EXU execute task to task communications between them. Before the message transmission, OPU is linked with EXU. Then OPU and EXU transfer the text message to each other. The format of text message is formalized as shown in Fig.2.

At EXU, the received text message is stored into a buffer area by the interface process of control program CSA90[6]. Subsequently the buffered text message is taken by interface subroutine and then executed by a periodic subroutine after decoding the text message. Both subroutines use a common sharable image composed of the status, values, parameters and so on. Both subroutines are registered in the EXU and selectively called by the OPU using the subroutine number. The text message consists of this interface subroutine number and a command message associated with a control procedure of the target devices. So the central job at OPU is to generate the text message according to the associated control procedures. The interval of a periodic subroutine can be controlled by the associated control program CSA90. The minimum interval time is 50 msec and can be increased by 50 msec integrals.

The communication network 'INS-Ethernet' is a standard network in our institute, whereas other network system is used in our institute. The new control system

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A New Architecture for Fermilab's Cryogenic Control System

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Abstract

In order to achieve design energy in the Tevatron, the magnet system will be operated at lower temperatures.[1] The increased requirements of operating the Tevatron at lower temperatures necessitated a major upgrade to the both the hardware and software components of the cryogenic control system. The new architecture is based on a distributed topology which couples Fermilab designed I/O subsystems to high performance, 80386 execution processors via a variety of networks including: Arcnet, iPSB, and token ring.

Introduction

The addition of "cold compressors" to the Tevatron's satellite refrigeration system, as well as the desire to dynamically balance the site's distributed compressor load, introduced additional performance requirements on the cryogenic control system. The required signal processing capabilities basically doubled, raising the number of I/O terminations to approximately 2,000 per satellite.

To effect global optimization the system's software also required significant enhancements. These included: support for global communications between refrigeration processors, an improved user interface to the finite state machines, both code and parameter down-loading capabilities, and substantially improved diagnostic support for the system's hardware.

Together, the performance criteria exceeded the capabilities of the original, Z80 based control system[2]. Therefore, a complete upgrade was warranted.

The new architecture

To achieve the desired performance with a minimum of hardware, we adopted a distributed architecture centered around Intel's 32 bit, 80386 microprocessor. Multibus II was selected as the hosting platform. We prefer it not only for the architectural advantages it offers, but also because of the existing support services which have already been developed for our front end computers[3]. The substantial amount of hardware and software that we were able to inherit allowed us to concentrate the majority of our efforts on developing smaller, more efficient I/O subsystems.

We partitioned the control system into six sectors following the physical distribution of satellite compressors around the Tevatron. Each sector consists of four satellite refrigerators and their associated compressor. The sectors are connected by a token ring network to effect global communications.

Each satellite unit is controlled by an Intel, iSBC 386/120 single board computer. The five CPU modules reside in a common Multibus II chassis which is located at the compressor installation. The loosely coupled architecture of Multibus II is ideally suited to this application. It supports protected, independent execution for each processor module, while simultaneously providing fair access to centralized system services. These services include: a Tevatron clock distribution processor, a "machine data" (MDAT) I/O module, global shared memory, a DOS based 386PC/AT for system initialization and diagnostics, and a token ring processor for global communications.

Inter-processor communications within the sector are accomplished over the parallel system bus (iPSB) which, in conjunction with the message passing protocol of Mutibus II, functions as a 40 megabyte per second local area network. The crate configuration is illustrated in Figure 1.

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Controls for the CERN Large Hadron Collider (LHC)

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Abstract

CERN's planned large superconducting collider project presents several new challenges to the Control System. These are discussed along with current thinking as to how they can be met. The high field superconducting magnets are subject to "persistent currents" which will require real time measurements and control using a mathematical model on a 2-10 second time interval. This may be realised using direct links, multiplexed using TDM, between the field equipment and central servers. Quench control and avoidance will make new demands on speed of response, reliability and surveillance. The integration of large quantities of industrially controlled equipment will be important. Much of the controls will be in common with LEP so a seamless integration of LHC and LEP controls will be sought. A very large amount of new high-tech equipment will have to be tested, assembled and installed in the LEP tunnel in a short time. The manpower and cost constraints will be much tighter than previously. New approaches will have to be found to solve many of these problems, with the additional constraint of integrating them into an existing framework.

I. LHC REQUIREMENTS

The Large Hadron Collider (LHC) is the major project planned by CERN[1], and will be its largest and most expensive ever. It will present control problems much greater than those experienced in earlier accelerators.

LHC is a superconducting twin beam hadron (proton initially) collider providing 7.7 TeV per beam at 10 Tesla bending field. The novel twin bore magnets in their cryostats will be installed in the same 27 kilometre tunnel as the LEP machine. The scale of the control problem can be gauged in part from the 1792 dipole and 392 quadrupole cryostats filling most of the circumference, in part from the number, about 2000, of insertion and corrector magnets and appropriate beam instrumentation. The difficulty of the control problem will come from the sensitivity of the superconducting magnets to quenching under beam loss from the 4725 bunches of 10^{11} protons at 400.8MHz, making 851mA. This problem is exacerbated by the time varying persistent currents and the need for strong collision insertions to achieve the targeted luminosity of over 10^{34}. These requirements will strain dynamic aperture and magnetic field control to the very limit.

As LHC will be built in the same tunnel as LEP, a lot of equipment and controls will be common to the two machines. A major objective will therefore be a seamless integration of LHC and LEP controls. This will not be easy, in part due to the much more difficult control problems of LHC, in part due to the wide separation in time between the construction of the two systems compared to the speed of evolution of controls technology. A challenge for LHC will therefore be to permit the use of the latest and cheapest controls technology in such a way that it integrates with existing technology, allows experience and algorithms to be maintained, and does not demand a difficult and costly upgrade of existing systems. Another objective to be borne in mind is the aim of having a single control centre for the whole of CERN on the LHC time scale.

II. MAGNETIC FIELD CONTROL

This will be the most difficult control problem for LHC. The magnetic field is determined not only by the voltages and currents from the 1400 power supplies, but also by "persistent currents" in the superconductor which vary with time depending on the history of the magnetic cycle. Fortunately HERA experience has shown these effects to be reproducible, hence eventually calculable and correctable. Corrections will be derived from magnet measurements during the construction and from on-line measurements from reference magnets. The final trimming will have to be done using single pilot bunches of first 10^9 then 10^{11} protons. After full beam injection, continuous feedback control will be required, especially immediately after injection and during beam squeezing.

A. Modelling Server

The solution envisaged is to use a modelling server which will re-calculate the power supply settings in real-time, using measurements from the reference magnets, beam measurements, past history of the magnetic cycle, and the magnet characteristic data-base. The update time will be between 2 and 10 seconds. Tests on an Apollo DN10'000 in the LEP control system indicate that the computational load will not be beyond the sort of on-line computer we can expect in the LHC time scale. Each power supply will have a microprocessor capable of interpolating the required voltages and currents between modelling server updates.

B. Fast Communications

A new communications system is being studied for LHC, in conjunction with SSC, in order to acquire the beam data and set the power supplies at the required rate[2]. This will use TDM communications technology and reflective memory com-

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A Performance Requirements Analysis of the SSC Control System

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Abstract
This paper presents the results of analysis of the performance requirements of the Superconducting Super Collider Control System. We quantify the performance requirements of the system in terms of response time, throughput and reliability. We then examine the effect of distance and traffic patterns on control system performance and examine how these factors influence the implementation of the control network architecture and compare the proposed system against those criteria.

I. Introduction

The Superconducting Super Collider Laboratory (SSCL) is a complex of accelerators being built in the area of Waxahachie, Texas. It will be fully operational at the end of the decade. The SSCL consists of six accelerators: a 1 Gev Linac, three booster synchrotrons (the 12 Gev low energy booster, a 200 Gev medium energy booster, a 2 Tev high energy booster) and two intersecting, contra-rotating 20 Tev synchrotrons that make up the Collider itself. The complex will occupy approximately 112 km of underground tunnels. There are estimated to be about 150,000 control points requiring remote control and interrogation in order to operate the accelerator and diagnose its condition.

II. Performance Requirements

A. Response time

The control system's response to operator requests should be such that response delays be unnoticeable to the operators. The minimum response time of the control system should be, in the absence of any other constraining factors, 20Hz.
In addition, it will be necessary to provide for higher rates, up to 1 Khz for some essential services like the quench protection monitors (QPM).

B. Throughput

In the Collider tunnel there are 5 Superconducting dipole magnets per half-cell and 968 half-cells per ring. Every 450m is an equipment niche (alcove) which controls 5 half-cells (200 niches). The HEB has 280 half-cells controlled by 24 Niches. The MEB consists of 200 half-cells controlled from 8 surface buildings and the LEB has 108 half-cells controlled from 6 surface buildings. Throughput requirements vary widely [Table 1]. The Linac is not considered here. The environmental (ENV) figures include niche temperature, power, smoke alarms, oxygen and water. The value in the column marked Locations indicates the number of Niches or equipment buildings for a particular machine. The value in the column marked Bytes indicates the number of bytes of raw data being generated at that location for each time interval indicated in the column marked Rate, which is the number of time intervals per second. The value in the column marked Bandwidth is the total number of bytes per second generated for that equipment type and is the product of the Locations, Bytes and Rate values. For the LEB BPM data rates have been set in this table at one tenth of the raw rate in order to conserve bandwidth.

The total amount of data generated site-wide by the SSCL is in excess of 250 Mbytes per second (2 Giga bits per second)[1,2].

C. Reliability

Total allowable unscheduled downtime for the control system is 30 hours in 4505 hours of operation per year. The control system will consist of 205 equipment locations consisting of 162 Collider niches, 24 HEB niches, 11 MEB buildings, 6 LEB buildings, the Linac and the control room complex. Each of these locations will have one communications element (Hub Gateway or multiplexor, depending on the communications architecture chosen) and up to 9 equipment crates.
If each of these 2050 elements (205 locations x 10 elements) is a "critical" system, then to achieve 30 hours of unscheduled downtime with a mean time to repair of 1.5 hours (20 incidents per year) each element would have to achieve a mean time between failure of 54 years [3]. It is therefore clear that other measures, such as the use of redundant systems, will be necessary in order to achieve the necessary reliability figures.

D. Capacity

The installed system should have a capacity at least 50% greater than the requirements stated above. It should furthermore be capable of being expanded by 400% without incurring any additional civil engineering costs or replacement of existing components, only expansion costs.

III. Operational Requirements

A. Data Accessibility

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The Computer Control System for the CESR B Factory

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Abstract

B factories present unique requirements for controls and instrumentation systems. High reliability is critical to achieving the integrated luminosity goals. The CESR-B upgrade at Cornell University will have a control system based on the architecture of the successful CESR control system, which uses a centralized database/message routing system in a multi-ported memory, and VAXstations for all high-level control functions. The implementation of this architecture will address the deficiencies in the current implementation while providing the required performance and reliability.

I. INTRODUCTION

CESR-B is an upgrade to the existing CESR facility.[1] The major part of the upgrade is the addition of a second storage ring in the existing tunnel. The two rings will operate with asymmetric energies (3.5 GeV and 8 GeV) and will intersect within the CLEO detector. The design luminosity is $3 \times 10^{33} cm^{-2}s^{-1}$ which will be achieved with 230 bunches in each ring.

The control system for CESR-B is also an upgrade of the existing control system.[2] The architecture is shown in figure 1. The MPM (Multi-Port Memory) contains the database and is accessible by the high-level computers and the BCCs (Bus Control Computers). The high-level computers are used to develop and run programs which interface with the operators and physicists to control and monitor the experiment. The BCCs manipulate and move data between the database and the accelerator hardware. Both the MPM and the interface hardware are mapped into the memory space of the BCCs. They only transfer data when requested to by the high-level computers.

It is important to remember the difference between the architecture of a system and how it is implemented. Within a well defined architecture, one can make hardware or software changes to improve some aspect of performance without affecting systems which are outside of the boundary of the control system.

II. DESIGN PROCEDURE

Having decided that the current CESR control system is a suitable model for the B factory, we proceeded to analyze the strengths and weaknesses of our system and the different needs of the new system. Part of this process was defining the scope of the control system.

A. Boundaries of the Control System

For a large design project, well defined boundaries are essential. At the boundaries, the needs of other people must be taken into consideration, and the design process requires communication between the designers and the users of the control system. Within the boundaries, the control system designers can do whatever is needed. We have defined the scope of the control system by defining interfaces for application programmers, instrumentation designers, and operators.

Application programmers must be provided a complete, well documented, set of functions which meet their needs. Programmers are not allowed to bypass these functions by using calls to lower-level routines. CESR uses approximately 35 functions.

Designers of instrumentation hardware are provided with a specification for constructing interfaces to the control system. This includes mechanical, electrical, and protocol details. Recommendations that simplify the control system are included, but not required. This encompasses things like avoiding write-only registers and not having read operations change the state of the system.

The actual implementation of the operator interface is a combination of efforts by both the application programmers and the instrumentation designers. However, it is essential to know the needs of the operators when designing the control system.

B. Special Requirements of the B Factory

We need to know what makes CESR-B different from CESR and how these differences affect the architecture and implementation of the control system.

The first question is how much larger will the new system be? At this early date, we do not have all of the details from the various design groups (eg. vacuum systems, magnet systems), but we do have general numbers. Combining this information with the fact that the amount of equipment in the tunnel will approximately double, we determined that the new control system will have roughly twice as many output control points as the current system.

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Standards and the Design of the Advanced Photon Source Control System*

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I. INTRODUCTION

The Advanced Photon Source (APS), now under construction at Argonne National Laboratory (ANL), is a 7 GeV positron storage ring dedicated to research facilities using synchrotron radiation. This ring, along with its injection accelerators is to be controlled and monitored with a single, flexible, and expandable control system. In the conceptual stage the control system design group faced the challenges that face all control system designers: (1) to force the machine designers to quantify and codify the system requirements, (2) to protect the investment in hardware and software from rapid obsolescence, and (3) to find methods of quickly incorporating new generations of equipment and replace obsolete equipment without disrupting the existing system. To solve these and related problems, the APS control system group made an early resolution to use standards in the design of the system. This paper will cover the present status of the APS control system as well as discuss the design decisions which led us to use industrial standards and collaborations with other laboratories whenever possible to develop a control system. It will explain the APS control system and illustrate how the use of standards has allowed APS to design a control system whose implementation addresses these issues. The system will use high performance graphic workstations using an X–Windows Graphical User Interface (GUI) at the operator interface level. It connects to VME–based microprocessors at the field level using TCP/IP protocols over high performance networks. This strategy assures the flexibility and expansibility of the control system. A defined interface between the system components will allow the system to evolve with the direct addition of future, improved equipment and new capabilities. Several equipment test stands employing this control system have been built at ANL to test accelerator subsystems and software for the control and monitoring functions.

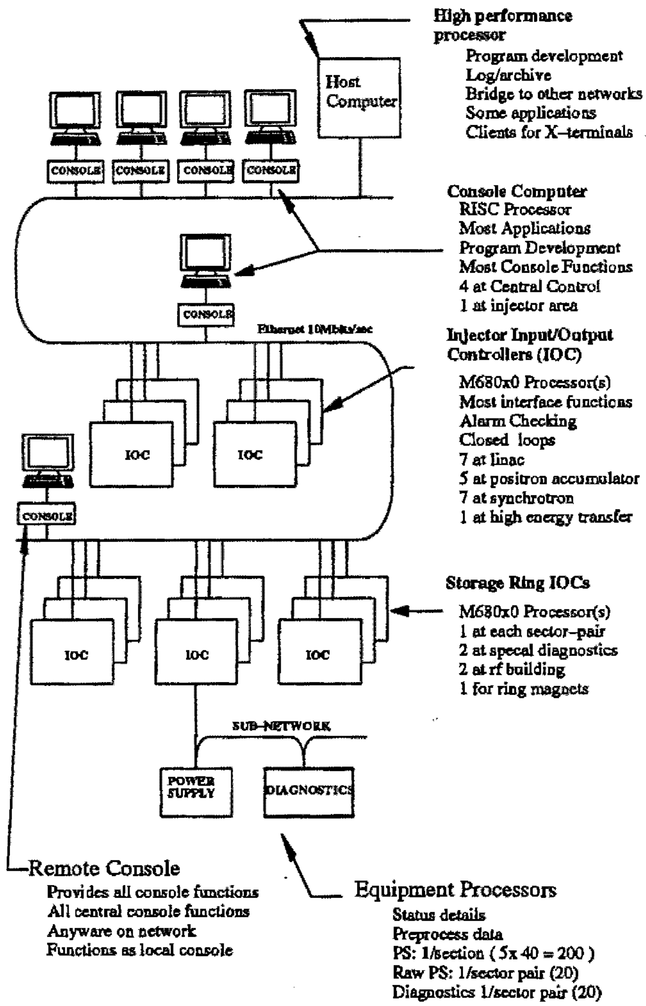

Figure 1. APS Control System

II. STANDARDS AND THE APS CONTROL SYSTEM

The APS control system must be capable of (1) operating the APS storage ring alone and in conjunction with its injector linacs, positron accumulator, and injector synchrotron for filling, and (2) operating both storage ring and injection facilities as machines with separate missions. The control system design is based on the precepts of high–performance workstations as the operator consoles, distributed microprocessors to control equipment interfacing and preprocess data, and an interconnecting network. In a paper presented at the 1985 Particle Accelerator Conference [1] we outlined our initial approach to the APS control system. In this paper we predicted

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The ESRF Control System; Status and Highlights

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1 Introduction

The European Synchrotron Radiation Facility[1][1] will operate a $6GeV$ e^-/e^+ storage ring of 850m circumference to deliver to date unprecedented high brilliance X-rays to the European research community. The ESRF is the first member of a *new generation* of Synchrotron Radiation Sources, in which the *brilliance* of the beam and the utilization of *insertion devices* are pushed to their present limits.

Commissioning of the facility's storage ring will start in spring 1992. A full energy injector, consisting of a 200MeV linear preinjector and a $6GeV$ fast cycling synchrotron ($10Hz$) of 350m circumference have been successfully commissioned during the last months.

The machine control system for this facility, which is under construction since 1988, is still under development, but its initial on-site operation this year has clearly made easier the commissioning of the preinjector plant.

A description of the current system is given and application software for start-up is briefly described.

2 Architecture

The ESRF control system is based on a multi-level architecture of distributed hard- and software processing units[2]. Logically the system is structured into four levels. From top to bottom we call them:

- Console Level (Presentation);
- Process Level (Applications);
- Group Level (Device Servers);
- Field Level (Equipments, Embedded Controlers).

On the lowest level, all equipments are interfaced; either by intelligent controlers, as they are delivered from the manufacturer, or by dumb interfaces. Equipments are logically grouped together on the group level. Grouping of equipments is done by similar functionality. The group level is responsible for hardware specific and real time I/O-operations. *Device servers* perform the task of hiding hardware specifics to the upper level. The process level represents that level of the control system where practically all higher level control tasks take place and where physics applications are processed. Powerful multitasking capabilities and fast processing is mandatory on this level. The presentation level presents the interface between the operators and the system. Within this level data entering from the lower level are presented graphically or are formatted to readable reports. Commands entered by means of interactive devices are decoded into events and finally passed as internal messages to the lower levels.

Physically the system is split into 2 levels. All nodes of the presentation and process level consist of UNIX based workstations and file/compute servers interconnected by Ethernet. The group level nodes are realised by VMEbus crates, equipped with 68030 CPU boards. These systems run the OS9 multitasking real time kernel/operating system. Every process level server connects to a private Ethernet segment onto which group level nodes it is in charge of are connected.

The physical boder line between group level and field level is fuzzy. In our system some dumb devices are directly interfaced to VME I/O-boards that are plugged into group level crates, but most dumb devices are interfaced by means of G64 crates. Groups of G64 crates, that interface classes of similar devices, are connected to multidrop highways that are mastered by group level crates. This multidrop highway[2] was developed at ESRF. However, intelligent devices with embedded controlers are, in the majority of cases, directly connected to VME (group level) crates[3].

3 Networks

Modern control systems are distributed[3, 4]. The larger the accelerator is, the more important is its network infrastructure. The ESRF control system is fully distributed and relies strongly on a high speed computer network.

Figure 1 gives an overview of the logical and physical implementation of the control system and its network.

Apart from the home-made multidrop highway all computer connections are based on the Ethernet(IEEE 802.3)

[1] (ESRF)

[2] we named it FBUS

[3] in the majority by RS422 or RS232 asynchronous serial links

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Centralized Multiprocessor Control System for the Frascati Storage Rings DAΦNE

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Abstract

We describe the status of the DANTE (DAΦne New Tools Environment) control system for the new DAΦNE Φ-factory under construction at the Frascati National Laboratories. The system is based on a centralized communication architecture for simplicity and reliability. A central processor unit coordinates all communications between the consoles and the lower level distributed processing power, and continuously updates a central memory that contains the whole machine status. We have developed a system of VME Fiber Optic interfaces allowing very fast point to point communication between distant processors. Macintosh II personal computers are used as consoles. The lower levels are all built using the VME standard.

I. DAΦNE

DAΦNE [1] is a two ring colliding beam Φ-Factory under construction at the Frascati National Laboratories (See Fig. 1).

Construction and commissioning is scheduled for the end of 1995.

The luminosity target is $\sim 10^{33}$ cm^{-2} sec^{-1}.

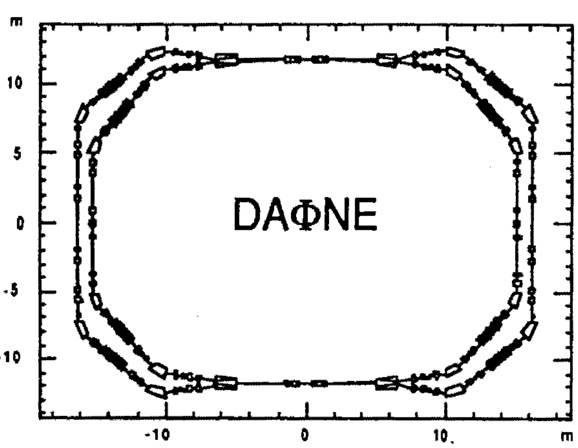

Fig. 1 : The DAΦNE Φ-Factory layout

II. SYSTEM STRUCTURE

Fig. 2 shows the general architecture of the control system. Three levels are defined:

PARADISE (PARAllel DISplay Environment) is the top level, implementing the human interface. Several consoles, built on Macintosh personal computers, communicate with the rest of the system through high speed DMA busses and fiber optic links.

PURGATORY (Primary Unit for Readout and GATing Of Real time Yonder) is the second and central level of the system. It essentially contains only a CPU and a Memory in a VME crate. The CPU acts as a general concentrator and coordinator of messages throughout the system. The central Memory is continuously updated and represents the prototype of the machine database.

HELL (Hardware Environment at the Low Level) is the third level of the system and is constituted by many (about 60) VME crates distributed around the machines.

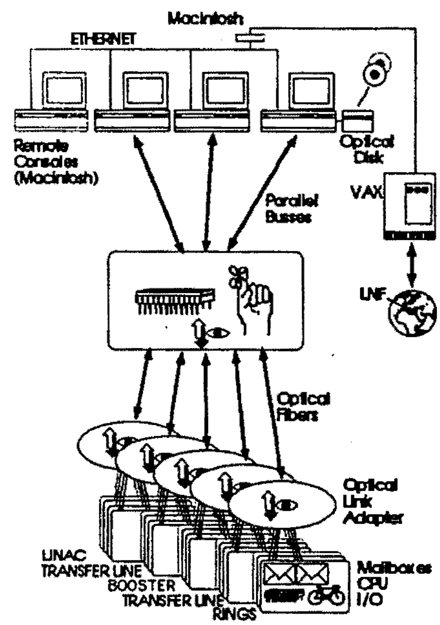

Fig. 2: Control System Schematic Diagram

A CPU in every crate performs control and information hiding from the upper levels.

VME is used throughout Purgatory and Hell

A first estimate of the system gives about 7000 channels to be controlled.

Centralized Communication Control

We have chosen an architecture based on a single central

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THE OPERATOR VIEW OF THE SUPERCONDUCTING CYCLOTRON AT LNS CATANIA

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Abstract

The upper level of a distributed control system designed for the Superconducting Cyclotron (SC), will be discussed. In particular, we will present a detailed description of the operator view of this accelerator along with the tools for I/O points management, data rappresentations, data archiving and retrieval. A dedicated program, developed by us, working under X-Window will be described as a starting point for a new man-machine interface approach in small laboratories opposed to the first industrial available packages.

I. INTRODUCTION

The SC developed at the Milan University, where was performed the first test on the magnetic field, has been moved to the final destination, at LNS in Catania. The work on the accelerator will start at the begin of the next year with the magnet excitation and the installation of the RF cavities. The extraction of the beam, injected in the booster by a 15 MV Tandem, is foreseen before the spring of 1993. The main features of this heavy ions accelerating facility are reported elsewhere [1] [2].

According to the experience gained in Milan on the control system during the first magnetic measurements, we planned improvements mainly on the upper level devoted to the man-machine interaction. The first console designed and realized in 1985-1987 [3], followed an old philosophy. Altough the main hardware and software choices had been proved satisfactory, it gave us a flexibility not so good as we expected.

Nowadays the availability of standard graphic software and the capability to create networks are the two features which make the workstation a pratical cost effective way to provide an universal environment for the development of the operator interface. It is possible to use powerful hardware and software standards which make straightforward the setting up of a network where hardware and software resources can be easily shared in a really efficient environment.

In the follow we will discuss the hardware and software architecture of the Superconducting Cyclotron operator console together with its performance measured during the test.

II. THE OPERATOR CONSOLE

In 1989, during the shut-down of the SC in Milan, we decided to review the structure of the console. Some general rules were fixed for the project.

- The architecure must be independent of the number of worksites in use: the insertion or the removal of a worksite must be invisible to the whole system, realizing in this way a real "easy expandible system".
- The architecture would allow to have the same graphical workstation conncted both in the main control room and in a remote place closed to the accelerator.
- The architecture of the console must be fully independent of the lower levels so that the choices made in process and plant levels don't influence the supervisor structure.
- The presentation level of the software must not require any practice in computer science and must be picture driven. The operator must be able to define its own working environment with few choices and the access to every information that he wants to deal with has to be guaranteed.
- The operations on an accelerator subsytem must be possible by each workstation but not at the same time. The display of all machine parameter must be possible on different workstations at the same time.
- The on line software configuration must be guaranteed by means dedicated programs taking advantage of a database.
- The allarms and malfunctioning logging task must be managed by a dedicated unit able to provide particular tools to help the operator in his trouble shooting job.
- The maintanance of the whole structure must be easy and centralized as much as possible on a single machine.

It was decided that the development of most of software would take not more than 3 man-years of work. The choice of the final solution was not easy and a lot of different considerations, like our experience with graphical workstations and their operating system, the estimated technical support avilable from vendors in our country, were taken into account. At last, we decided to implement our hardware architecture on a Local Area VaxCluster (LAVC) of 3100 Vaxstations with a µVax 3100 as boot member. A gateway was provided towards the lower levels. A µVax II was dedicated to this task along with the storage of the memory map of all sensors and actuators. Two 80386 PCs were dedicated to allarm logging and to manage the data necessary for the application tasks.

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The UNK Control System

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Abstract

The IHEP proton Accelerating and Storage Complex (UNK) includes in its first stage a 400 GeV conventional and a 3000 GeV superconducting ring placed in the same underground tunnel of 20.7 km circumference. The beam will be injected into UNK from the existing 70 GeV accelerator U-70. The experimental programme which is planned to start in 1995, will include 3000 GeV fixed target and 400*3000 GeV colliding beams physics. The size and complexity of the UNK dictate a distributed multiprocesssor architecture of the control system. About 4000 of 8/16 bit controllers, directly attached to the UNK equipment will perform low level control and data acquisition tasks. The equipment controllers will be connected via the MIL-1553 field bus to VME based 32-bit front end computers. The TCP/IP network will interconnect front end computers in the UNK equipment buildings with UNIX workstations and servers in the Main Control Room. The report presents the general architecture and current status of the UNK control.

1.Introduction

The UNK complex will combine - in one tunnel of 20.7 km circumference - a 400 GeV conventional magnet synchrotron (UNK-I) and a 3000 GeV superconducting synchrotron/storage ring (UNK-II). At a later stage a second superconducting ring (UNK-III) may be added with the aim of doing proton-proton collider physics at 6 TeV (Figure 1).

The UNK-I is injected at 70 GeV from the existing proton synchrotron U-70. For one filling up to 12 pulses from U-70 may be stacked, accelerated to 400 GeV and transferred to the UNK-II which in turn accelerates them up to 3 TeV.

Three main modes of operation are presently foreseen.

1. Fixed Target at 3 TeV: fast or slow extraction will send the 3 TeV beam to the fixed target experimental area. During the acceleration in the superconducting ring, U-70 may produce beams for its own 70 GeV experimental area.
2. Colliding Beams at 3 + 0.4 TeV: the beams from the UNK-II and UNK-I are made to collide. For this the UNK-I is operated first as booster and, after field reversal, as a storage ring run at 400 GeV.
3. Colliding Beams at 3 + 3 TeV: the UNK-I will first inject into one superconducting ring and, after field reversal, into the second one.

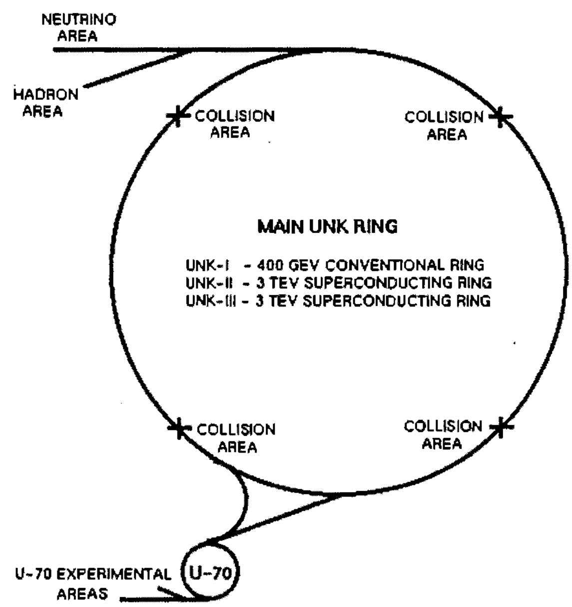

Figure 1 Layout of the UNK Complex

The accelerator controls equipment will be distributed over 24 on-surface buildings situated mainly along the accelerator ring. In one of the these is the Main Control Room (MCR), the other ones house the remote nodes of the control system. The latter are totally controlled from the MCR and are in general not manned. The typical distance between any two adjacent buildings is about 1.8 km and the maximum is about 3.5 km.

The more than 3500 superconducting magnets require a cryogenic plant and elaborate distribution, recovery and safety installations and their concomitant controls in the surface buildings around the ring tunnel.

The UNK operation is supported by general electricity and water distribution networks, tunnel ventilation, radiation protection, fire safety and other utilities which require highly reliable controls with 24 h/day 365 d/year availability.

The secondary beamlines and external experimental areas cover an area of roughly 12 km length. Controls for their

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MOSCOW UNIVERSITY RACE-TRACK MICROTRON CONTROL SYSTEM: IDEAS AND DEVELOPMENT.

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Abstract.

Moscow University race-track microtron (RTM) control system is a star-shape network of LSI-11 compatible microcomputers. Each of them is connected with RTM systems via CAMAC; optical fiber coupling is also used. Control system software is designed on Pascal-1, supplemented with real time modules and Macro. A unified real time technique and reenterable data acquisition drivers allow to simplify development of control drivers and algorithms. Among the latter three main types are used: DDC methods, those, based on optimization technique and algorithms, applying models of microtron's systems. Man-machine interface is based on concept of the "world of accelerator". It supports means to design, within hardware possibilities, various computer images of the RTM.

INTRODUCTION.

Moscow University race-track microtron - when it's construction will be finished - is to produce 175 MeV 100% duty factor electron beam with low transverse emittance (0.05 mm*mrad) and up to 0.01% energy monochromaticity [1,2]. To support means for easy programming of microtron's behavior, when being adjusted, and to meet requirements of experimental work, computer-based control system is to be developed. It's configuration is shown on fig. 1

HARDWARE.

Each micro computer of the control system is a 1-PCB LSI-11 compatible machine (EIS,FIS CPU; 1 mips; 56 Kb RAM). In control station it's connected with CAMAC via JCC-11 compatible crate-controller. Among CAMAC modules the following types are used: output and input registers (standard and specialized), FET multiplexers, 13,14,16 bit ADCs, step motor drivers. To prevent inadmissible interference, control system is isolated electrically from accelerator's equipment. For this purpose optically coupled measurement devices are used. Their terminal modules can be of three types: 19 bit TTL transmitter or receiver, 16 multiplexed a dozen bit ADCs or eight 12-bit DACs. Control stations (three of them in operation now) are connected via RS-232C interface in a star-shape network, formed by concentrator station. The latter is also tied with host-machine, used for software development and system loading. Man-machine interface and data-bases station is linked up with network like a control station. Concentrator machine and control stations have no any extra memory storage except CPU RAM. Man-machine and data bases station includes two microcomputers. One of them supports graphics, another handles data bases and communication protocols. This station, as well as host machine, is supplied with disc memory - including electronic one. Alphanumeric displays (VT-100) and some other peripherals are also attached. Among them - RS-232C interface, allowing to link up control system with external computer or network. Man-machine interface will also be supplied with four infinite-turning knobs to facilitate manipulation with one, two or three dimensional objects (control parameters value, terminal cursors etc).

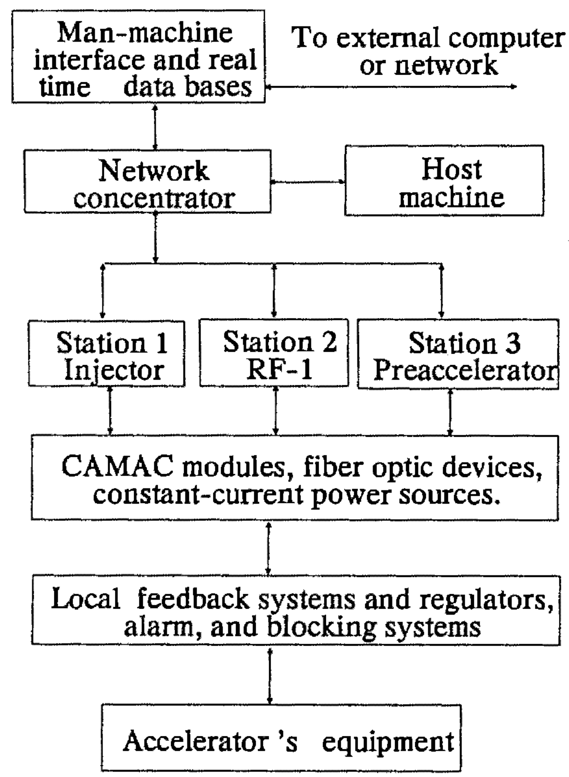

Fig. 1. Block diagram of Moscow University RTM control system.

SOFTWARE.

Compilation tools.

Basic compilation tools are shown on fig. 2. Source Pascal code with Macro insertions is being compiled with Pascal-1. Then a specially designed improver heightens an effectiveness of resulting Macro code. Afterwards, on Macro stage, it's being combined with CAMAC support

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Present Status of Control System at the SRRC

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ABSTRACT

The modern control technique was used to design and set up a control system for the synchrotron radiation facilities at the synchrotron radiation research center (SRRC). This control system will be finally to operate the dedicated machine to provide the 1.3 GeV synchrotron radiation light. The control system will control and monitor the components of storage ring, beam transport and injector system. The concept of the philosophy is to design a unique, simple structure and object-oriented graphic display control system. The SRRC control system has the major features such as two level architecture, high speed local area network with high level protocol, high speed microprocessor based VME crate, object-oriented high performance control console and graphic display. The computer hardware system was set up and tested. The software in top level computers which include database server, network server, upload program, data access program, alarm checking and display, as well as graphics user interface (GUI) program were developed and tested. The operational system and device driver on the field level controller were implemented. The overall performance of the SRRC control system were tested and evaluation. The preliminary results showed that SRRC control system is simple, flexible, expandable and upgradable open system to control and monitor devices on the small scale synchrotron radiation facility.

I. INTRODUCTION

The 1.3 GeV synchrotron radiation facility is going to construct at SRRC to provide a low emittance and high brilliance light source. The dedicated synchrotron light source will include three subsystems that are a turn key 1.3 GeV electron full energy injector, beam transport line and storage ring. The 1.3 GeV full energy electron injector was constructed to Scanditronix AB at Sweden and installed at SRRC site. The injector is going to commission within 2 or 3 months. The beam transport line has been designed and its major component was also fabricated partially. The storage ring with triple bend achromat lattice [1] has been designed and the most components were constructed and passed its qualification of the specification.

The control system at SRRC provides a unique control and monitoring three subsystems which include the injector, the beam transport line and the storage ring facilities. The 1.3 GeV energy electron injector is composed of a 50 MeV linear accelerator and 1.3 Gev booster synchrotron accelerator. The control system of booster synchrotron can be run in a turn-key system and/or to be integrated into SRRC control desk to form an unique control system. The design concept is to standardize the same computer architecture, digital communication network with some protocols and some database structure as well as some console computer. The control system of the electron injector can play as a stand-alone subsystem to test and commissioning machine as well as machine study for booster synchrotron.

The control system of SRRC is cost-effectively designed by using recent developed computer technology [2,3] and modern control technique [4-9]. Two level hierarchical computers, process and console computer as a top level and multiple intelligent local controllers (ILC) as a low level, was configured. One process computer and several console computers at top level provide the database management and maintenance, devices control and monitoring, data logging and archiving, machine modeling, object-oriented graphical display. The lower level computers are multiple VME crate based system which handle device related data acquisition and control as well as local interlocking functions. It simplifies the architecture of control system at SRRC. The upper and lower level computers are connected by ethernet using high level protocol.

The process computer will handle the static and dynamic data base. It also offers to carry out the calculation of the electron orbit and simulation of the machine physics parameter. It is a high speed computing, multi-task and muti-user virtual memory system (VMS), and high through input/output (I/O) capability. The console computers will play a similar job as a process computer except maintenance of the database. The console computer plays an important role to operate and monitor the synchrotron radiation facility using man-machine interface that is developed based on the concept of the object-oriented graphic display. This is the most recent development on the third generation of the synchrotron radiation facility [7-9].

The ILC is a field level (or called device level) controller which performs the local data collection, local interlocking and closed loop control for the components and/or the equipment of the various system. It is also very important for the real time feedback control system.

II. COMPUTER HARDWARE SYSTEM

Two level hierarchical computer configuration has been designed and installed partially at this moment. The hardware configuration of the control system at SRRC is shown in figure 1. The top level computers are composed by one process computer and several console computers. The VAX 6000 model 610 supermini computer is chosen as a process computer. The VAXstation 3100 model 76 is selected as a console computer. The big semiconductor and mass storage capacity as well as high speed I/O peripheral devices are also considered and configurated.

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Status Report on Control System Development for PLS*

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Abstract

Emphasizing reliability and flexibility, hierarchical architecture with distributed computers have been designed into the Pohang Light Source (PLS) computer control system. The PLS control system has four layers of computer systems connected via multiple data communication networks. This paper presents an overview of the PLS control system.

Introduction

The accelerator control system provides means for accessing all machine components so that the whole system could be monitored and controlled remotely. These tasks include setting magnet currents, collecting status data from the vacuum subsystem, taking orbit data with beam position monitors, feedback control of electron beam orbit, regulating the safety interlock monitors, and so forth. To design a control system which can perform these functions satisfactorily, certain basic design requirements must be fulfilled. Among these are reliability, capability, expansibility, cost control, and ease of operation.

Considering above requirements, the PLS accelerator topology, available resources, special accelerator hardware requirements and personal preference, we propose a hierarchical system architecture. To implementation of the control system, highly commercial approach should be made because of the tight construction schedule. Using well proven technology will promote reliability, and reduce the development effort. A development environment is set up to develop the prototype of beam close orbit correction system which is to damp up to 15Hz movements. The Beam close orbit correction system will use DSP(Digital Signal Processor) board for the fast computation. All BPM electronic modules and corrector power supply interface I/O modules for one acromat will be put into one VXI crate.

Hardware Hierarchy

To monitor and control the thousands of signals for PLS, it is desirable and cost-effective to establish a distributed control system based upon microprocessors. The PLS control system has a hierarchical structure as shown in Fig.1. The hierarchy consists of four layers, each of which has a different role. The four layers

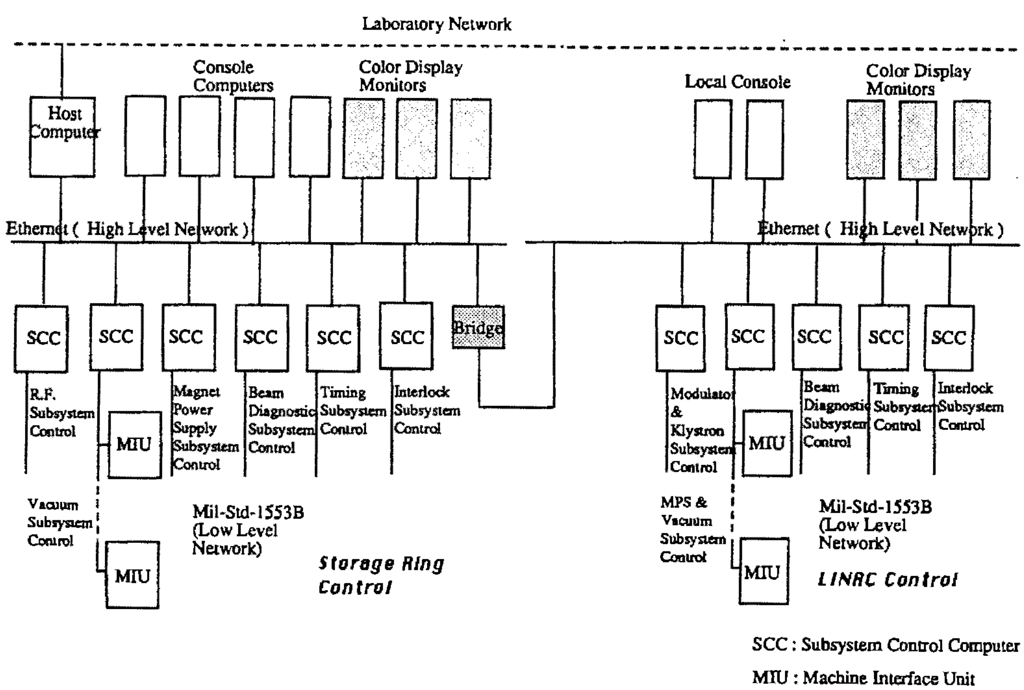

Figure 1. PLS Control System Architecture

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Design of SPring-8 Control System

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Abstract

The control system of SPring-8 facility is designed. A distributed computer system is adopted with a three-hierarchy levels. All the computers are linked by computer networks. The network of upper level is a high-speed multi-media LAN such as FDDI which links sub-system control computers, and middle are Ethernet or MAP networks which link front end processors (FEP) such as VME system. The lowest is a field level bus which links VME and controlled devices. Workstations (WS) or X-terminals are useful for man-machine interfaces. For operating system (OS), UNIX is useful for upper level computers, and real-time OS's for FEP's. We will select hardwares and OS of which specifications are close to international standards. Since recently the cost of software has become higher than that of hardware, we introduce computer aided tools as many as possible for program developments.

I. INTRODUCTION

The SPring-8 facility consists of an 8 GeV storage ring of 1436 m circumference with a natural emittance of 7.0 nmrad, an injector linac of 1 GeV and an 8 GeV synchrotron. Figure 1 shows the layout of the facility. Construction starts in 1990, and the first stored beam is foreseen in 1998 [1]. The construction of control system will start in 1994.

From the designer's viewpoints, the control system consists of the following parts:

1) Computer System;
 1-1) Host and front end computers;
 1-2) Network system;
 1-3) Software:
2) Interlock System;
3) Analog Signal Observing System;
4) Timing System;
5) Television Network System;
6) Links with other System:

II. DESIGN CONCEPTS

Followings are the design concepts of SPring-8 control system:

1) Distributed processors system which are linked by high-speed networks.
2) Sub-system control computers are loosely coupled, due to different accelerator construction schedules and for the convenience of independent operation at maintenance time.
3) In normal operation, all the accelerators are operated at one control room by small number of operators.
4) VME and MAP for front end processors and networks, respectively.
5) PLC (Programmable Logic Controller) for fixed control sequence.
6) Real-time operating system for VME.
7) For high productivity of application program;
 7-1) Object-oriented programming;
 7-2) Computer aided program developing tools;
 7-3) Computer aided operation tools:
8) Standard hardware and software.

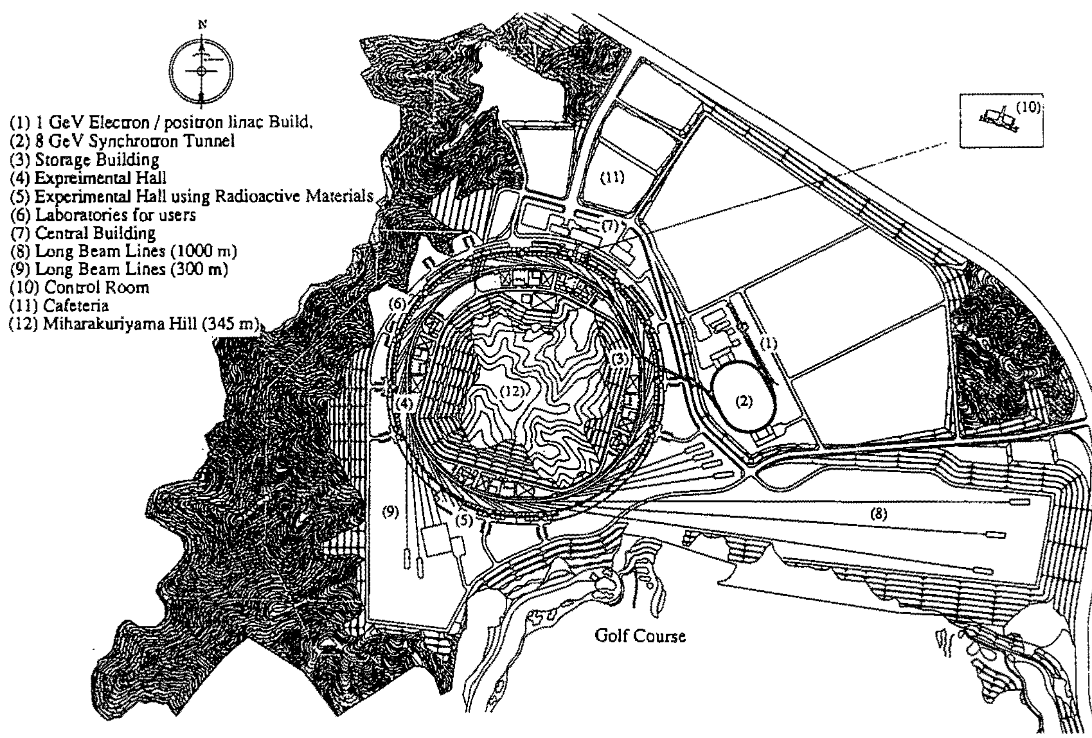

Fig. 1 Layout of the SPring-8.

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Design of a Control System of the Linac for SPring-8

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Abstract

The design of a control system of the linac which is a large scale system including many unstable components like klystrons and modulators. The linac for SPring-8 requires to be operated automatically for injection to the synchrotron. Under these conditions, we chose a distributed control system architecture of a single layer net-work to simplify the protocol of the net-work between the linac, the booster synchrotron and the storage ring. A VME computer of 68030 is put in every modulator of the linac, and all control signals are gathered to the nearest VME computer. OS-9 and OS-9000 are on trial for investigation of the performances. TCP/IP is tentatively chosen as a protocol of the net-work, but we expect that MAP/MMS makes a high performance, and we are preparing a test of it.

INTRODUCTION

We decided that all hardware should be selected from ready-made machines for security of reliability, and our needs is satisfied at low cost without any customizing modules. Because this linac will be used on commercial base, reliability is the most importance for this control system. Moreover, easiness to use is necessary as a user oriented system. This linac consists of 26 pairs of a accelerator section and a klystron, so control signals mainly exist around modulators. Every signal is connected to the nearest VME computer in the modulator. 26 VME computers are connected to the flat network of one layer. Each VME computer works for a modulator, magnet power sources, vacuum pumps, RF phase control and monitors. Software of 26 VME computers are almost same, and it is easy to check whole performance of this system by a test bench of one set.

CONFIGURATION OF THE SYSTEM

A.Hardware

MVME-147s(Motorola) is selected as a CPU board, and it is set in a cage of 20 plots. Digital input/output boards are photo-isolated type, and analog input/output boards are two type of 12bit and 16bit. All signals directly come to the computer through a interface circuit of no CPU, but signals of monitors must have interface devices to establish satisfactory performances.

B.Software

The operating system is OS-9, and the language is C, and partly assembler is used. To select OS, VxWorks, VRTX, LynxOS, OS-9000 and others are check up. OS-9 is selected at the points of reliability, ability of stand alone work without development systems and suitability for bottom up build of a system. Applications and libraries will be made from practical use of object oriented programming.

STRUCTURE OF PROCESS

Every task consists of a control process, file-managers and device drivers. To get higher flexibility, all parameters are described in several parameter-files, and processes have no inner parameters.

A.Communication process

The data format of communication between processes is the same as the format of data through the net-work. If one process send a event (or a signal) to the out of one's cage through a network, the event is received by a communication process. The communication process searches the network address of the cage to which the target process belongs, and it send the event signal as a datagram to the cage. The address of machines are not fixed. The machine address resolution procedure(MAR procedure) defined machine addresses. When a searched process name belongs to a machine, the MAR process of the machine answers its address by broadcast.

B.Logging process

Most of the data sets are logged by a double buffered method. A double buffered method is combination of a ring buffer and a event buffer. The ring buffer stores continuous data of short interval, and if any troubles appear, shifting of the ring buffer is stopped to trace of the origin of the troubles. The event buffer stores log of status for long term.

C.Interlock process

Inter lock signals must be taken by hard wires without computers. But it is able to reduce the wires by a inter lock bus system. In this linac, 26 modulators are almost same, and inter lock signals are classified into different emergency

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CONTROL SYSTEM FOR HIMAC SYNCHROTRON

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Abstract

A control system for HIMAC synchrotron has been designed. The system consists of a main computer, console workstations, a few small computers and VME-computers connected via Ethernet. The small computers are dedicated to the control of an injection line, an extraction line and an RF system. Power supplies in main rings are controlled by the VME-computers through FDI/FDO, DI/DO modules. This paper describes an overview of the synchrotron control system.

INTRODUCTION

HIMAC is a heavy-ion accelerator complex for the clinical treatment of tumors and now under construction at National Institute of Radiological Sciences. It consists of an injector, a synchrotron, a high-energy beam transport and an irradiation sub-systems. Heavy-ions with a charge-to-mass ratio as small as 1/7 are accelerated up to 6 MeV/u through an RFQ and Alvarez linacs and injected to the synchrotron sub-system.

The synchrotron sub-system has an injection line, an extraction line and a pair of separated function type synchrotron rings with almost the same structure. These rings operate independently at different energies and same ion-species except that power supplies of two rings are 180° out of phase each other. The output energy of each ring is designed to be variable in a range of 100 - 800 MeV/u for ions with $q/A = 1/2$. The general description about the HIMAC synchrotron was given in the previous article[1].

An overall control system for HIMAC consists of a supervisor computer and four sub-system control computers connected via Ethernet as shown in Fig.1. The supervisor computer is used for the global control of the whole system of HIMAC. It is also linked by hardware and/or software to the other equipments in this facility such as a water-cooling system, an air-conditioning system and a radiation safety system. The sub-system computers control individual devices and carry out programmed sequences for device groups. The control system for the injector was already reported[2]. The control system for the synchrotron is also

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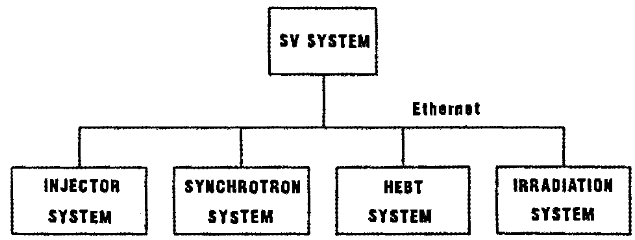

Fig. 1: A total control system for HIMAC consists of a supervisor computer and four sub-system control computers.

designed in the same manner, that is, 1) each system is operated rather independently by reducing the data to be transferred each other, and 2) hardware and software concerned with a man-machine interface must be standardized among all sub-systems.

SYSTEM CONFIGURATION

The synchrotron sub-system has many devices of different operational characteristics, for example, dc power supplies in the injection and the extraction lines, high-voltage power supplies in the RF system and the power supplies in the main rings operated with patterns or pulses. In order to handle these devices of different types efficiently and to reduce the load of the main computer, we adopted a distributed and hierarchical structure. A schematic view of the synchrotron control system is shown in Fig.2. Components and their functions are as follows.

A main computer and console computers

A main computer serves mainly as a man-machine interface and a file server. DEC VAX4000/300 is proposed for this purpose under VMS with 64 MB memory, 3 GB disk and communication interfaces for RS-232C, GP-IB and Ethernet. In the HIMAC system, parameters such as current values, current patterns, timing relations etc. are saved as a parameter file in the main computer and referred as the reference data in the next operation of the identical condition. The main computer has to manage this database and carry out programmed start-up and shut-down sequences using these files.

For a man-machine interface two operator consoles are available corresponding to two rings. Two VAX Station

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Digital Control of the Superconducting Cavities for the LEP Energy Upgrade

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Abstract

The superconducting (SC) cavities for the LEP200 energy upgrade will be installed in units of 16 as for the present copper cavity system. Similar equipment will be used for RF power generation and distribution, for the low-level RF system and for digital control. The SC cavities and their associated equipment however require different interface hardware and new control software. To simplify routine operation control of the SC cavity units is made to resemble as closely as possible that of the existing units. Specific controls for the SC cavities at the equipment level, the facilities available and the integration of the SC cavity units into the LEP RF control system are described.

I. Introduction

The RF system for LEP phase 1 consists of a total of 128 RF accelerating/storage cavity assemblies operating at 352 MHz, providing a total circumferal voltage of 400 MV. The cavities have been installed around interaction points 2 and 6 in the form of eight individual RF units. Each consists of 16 cavities, two 1 MW klystrons, DC high voltage power converter, low-level electronics and controls. For the LEP200 energy upgrade to 90 GeV, requiring 2000 MV, a further 192 superconducting (SC) cavities will be installed in 12 new RF units, two at each of points 2 and 6 and four at each of points 4 and 8. The RF frequency for the SC units is the same as for the copper units and as far as possible they will use identical equipment i.e. klystrons, power converter, low-level equipment and controls.

The SC cavities are housed in groups of four in a common cryostat to make up an "RF module". Initially only one klystron will be installed per unit but there is provision to add a second for higher beam intensities.

Control of the SC cavities and associated equipment is based on the same principles as for the copper cavities with the same type of interface equipment and software. To render overall operation as straightforward as possible differences between the two types of RF unit are taken into account by local software. Unlike the copper cavity units the SC units can be run in different configurations e.g. four, eight, 12 or 16 cavities and with either one or two klystrons per unit. The configuration must be taken into account by the local software. With two klystrons SC cavity units could be operated more effectively as two "sub-units" of eight cavities and one klystron sharing the common HV power supply. This option is allowed for in the hardware layout and software.

At present one unit with 12 SC cavities is operational in LEP and further units will be installed gradually up to the completion of the project, planned for the beginning of 1994.

II. Controls and Instrumentation for the LEP SC Cavities

Within the RF unit the various pieces of equipment associated with each major element of the unit are grouped together and controlled by a G64 bus standard based 'Equipment Controller' (EC). As for the copper cavity units there is one EC for each SC cavity but for each RF module there is an additional EC for cryogenics data. The EC is of modular construction and maximum use is made of a small range of interface cards. Standard modules are used to interface the following equipment :

- Cavity tuning systems,
- RF power measurement,
- RF window and helium gas return heating,
- HOM coupler fundamental mode power measurement,
- Helium gas pressure measurement,
- Helium gas valve control,
- Cryostat insulating vacuum,
- Cavity vacuum.

Interlock protection systems exist to switch off cavity tuning, RF or the HV power converter in the event of a fault or unsafe condition. These systems are largely contained within the ECs in the form of standard interlock modules and G64 readout interfaces which provide fault status and record trip sequences. For the SC cavities a "beam dump" interlock has been added. In the event of very high helium gas pressure or low liquid helium level, RF is switched off in all RF units.

For temperature measurements in the cavity a dedicated module inside the cavity EC measures up to 32 temperatures from signals from Pt100 sensors at various critical points. Conversion of voltage levels to temperature values in degrees Kelvin is done by the EC. Independent hardware logic inside the module triggers RF or tuner interlocks in the event of a change outside preset levels stored in EPROM. Fault information is stored and can be read via the the G64 bus.

A dedicated module in the cryostat EC provides a readout of liquid helium level in the cryostat. This, together with the gas pressure readings and RF levels, is made available via hard wired links to the regulation system of the cryogenics plant.

The design of the above equipment and interface hardware has been finalised and the material for the 180 cavities yet to be installed is being manufactured in outside industry.

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A PC BASED CONTROL SYSTEM FOR THE CERN ISOLDE SEPARATORS

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Abstract

The control system of the two isotope separators of CERN, named ISOLDE, is being completely redesigned with the goal of having a flexible, high performance and inexpensive system. A new architecture that makes heavy use of the commercial software and hardware available for the huge Personal Computer (PC) market is being implemented on the 1700 geographically distributed control channels of the separators. 8 MS-DOS™ i386-based PCs with about 80 acquisition / control boards are used to access the equipments while 3 other PCs running Microsoft Windows™ and Microsoft Excel™ are used as consoles, the whole through a Novell™ Local Area Network with a PC Disk Server used as a database. This paper describes the interesting solutions found and discusses the reduced programming workload and costs that are expected to build the system before the start of the separators in March 1992.

I THE ISOLDE PROJECT

The ISOLDE project consists of the move of CERN's Isotope Separators and their experimental area from the recently de-commissioned Synchrocyclotron to a beamline served by the Booster Synchrotron [1] [2]. A new control system was required.

Traditionally, control systems for accelerators have been designed based on specified functionality, and the hardware & software tailored to optimize potential utility. Frequently however, this results in 'home-grown' products which remain incomplete and are overtaken by the rapid advances of the massive industrial base of commercial products.

The ISOLDE Project was taken as an opportunity to explore the extreme opposite approach for the control system. Namely to use 'market-leader' commercial software & hardware available for the huge PC market, with in-house development limited to the necessary software & hardware interconnects. This represents an experiment in providing an inexpensive, user friendly control system, requiring a minimum of manpower both for the implementation & for subsequent maintenance.

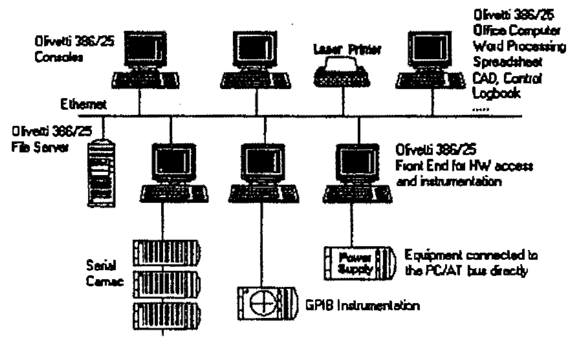
II THE CONTROL SYSTEM ARCHITECTURE

The new architecture [3] [4] [5] being installed reuses the old camac hardware while allowing an evolution of the system towards modern solutions.

Computers, Network and Control boards

The Isolde Control system is simple. It has Olivetti personal computers (PC) at all levels connected using the general purpose Ethernet network available side-wide.

As console in the control room, Olivetti 386/25 are used. i486 based PCs may be introduced next year. The console computers are equipped with 21 inch monitors providing a graphic resolution of 1024 x 768 pixels on 16 colors. Apart from high resolution monitors, the console computers are identical and fully compatible with the several hundred PCs available in the offices as local workstations [6].



The Isolde control system architecture

The personal computers connected to the equipment are called *Front End Computers* (FEC) and are also Olivetti 386/25. The performance of these computers is entirely satisfactory and 80286 PCs have enough CPU power to drive the equipment. In fact for some FEC applications, old IBM AT computers are used, recuperated from the initial Large Electron Positron Collider (LEP) front end controls, now replaced by faster Olivetti PCs. The Front End PCs are identical in configuration to the Office PCs except that they have additional boards for control.

The kind of control/acquisition boards supported in this architecture are:

- CAMAC, to allow the recuperation of all the hardware in the existing control system.
- GPIB to drive sophisticated instrumentation
- Industry Standard Architecture (ISA), alias PC/AT, boards that plugs into the PC directly or in ad hoc extension chassis.

A wide offer of this last type of boards exists and it has, for the moment, being restricted to Analogue to Digital converters (ADC), Digital to Analogue (DAC), Digital Input and Output (DIO), timer interrupts and external interrupt boards and RS232.

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STATUS OF THE CONTROL AND BEAM DIAGNOSTIC SYSTEMS OF THE CRYRING PROJECT

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Abstract—CRYRING is a facility for research in atomic, molecular and nuclear physics. It uses a cryogenic electron beam ion source, CRYSIS, together with an RFQ linear accelerator as injector into a synchrotron/storage ring for very highly charged, heavy ions. The first circulating beam was achieved in december 1990. The status of the systems for control and beam diagnostics are described.

INTRODUCTION

The CRYRING project [1] is centered around a synchrotron/storage ring of maximum rigidity 1.44 Tm, corresponding to an energy of 24 MeV per nucleon at a charge-to-mass ratio $q/A = 0.5$. It is mainly intended for highly charged, heavy ions produced by an electron-beam ion source (CRYSIS).

Light atomic or molecular ions can also be injected from a small plasmatron source (MINIS). Ions from the ion sources are accelerated electrostatically to 10 keV per nucleon and transported to a radiofrequency-quadrupole linear accelerator (RFQ) which brings them to 300 keV per nucleon. The ions are inflected electrostatically into the ring where they are accelerated using a driven drift tube. The stored ions will be cooled by an electron cooler. Fig. 1 shows a layout of the CRYRING facility.

The control system is based upon the LEAR (Low Energy Antiproton Ring) control system at CERN [2]. The principles of the system, the main part of the software and some parts of the actual hardware implementation are copied from the LEAR system. A substantial amount of development work has nevertheless been put into the CRYRING control system in order to adapt it to our operational needs which are partly different from the ones at LEAR.

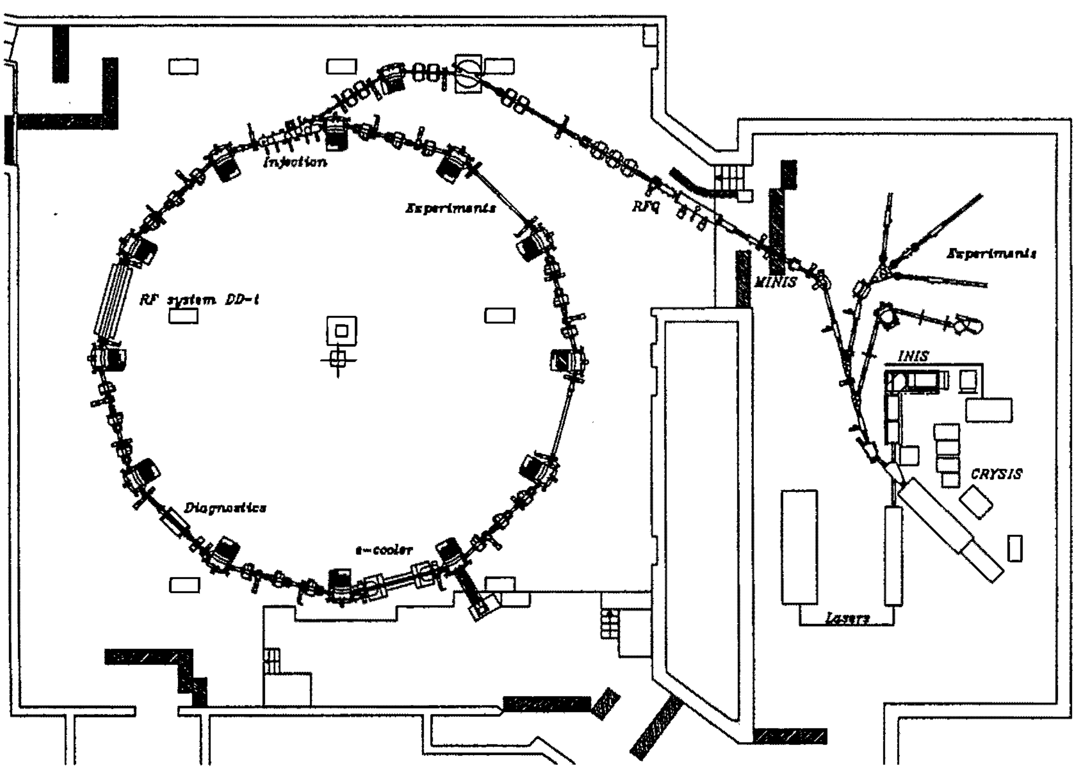

Fig 1 CRYRING layout.

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MAGNET TEST FACILITY CONTROL SYSTEM FOR SUPERCONDUCTING MAGNETS OF UNK

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1. Introduction

An UNK Magnet Test Facility (MTF) is being constructed to provide cryogenic, electrical and magnet tests of superconducting (SC) magnets of UNK. The main parts of it are:

- The cryogenic system consisting in its turn of the central liquefier, ten satellite refrigerators, two compressors, purification system and transfer lines. The central liquefier supplies the satellite refrigerators with liquid helium. The liquefier is manufactured according to the scheme incorporating precooling by liquid nitrogen, two turbine expanders and a wet expander.

- Four 8 KA, 24 V, ramped Power Supplies (PS) for cold testing of SC magnets, two 3 KA PS's for instrumentation testing and calibration.

- Test facility in its turn consisting of:

a) two dipoles and one quad benches for warm measurements;

b) eight dipoles and two quad benches for cold measurements;

c) two benches for instrumentation.

Relevant parameters and technique are given on table:

	Item	Parameter	Technique
1	Reference and calibration dipoles	Axis field	NMR - method in the central region and Hall - method at the end parts
		Multipoles	Rotating coils
2	Dipoles and quads measurements	Effective length Multipoles	Rotating coils NMR
		Field angle Magnetic axis	Stretched wires
		Dynamic multipoles	Stepwise coil rotation Measurement of transition process after dB/dt→0

The systems for warm measurements of SC coils and cold measurements of quads, including measurements of the magnetic axis location and alignment of the reference target, are being developped jointly with Saclay (France).

Total production rate of facility intended to be 2,4 SC magnets per day.

Such a complex of equipment requires a Control system which provides automatic monitoring, control of equipment, data aquisition and storage into files of magnets. Taking into account the difference between 3 pieces of an equipment (cryogenics, PS's and electrical/magnet measurement stations) Control system is designed as a mixture of 3 different subsystems with different phylosophy, but connected by LAN, sharing the same Host Computers, and based on the same hardware and computers.

2. Hardware Configuration

The hardware configuration is shown on Figure. PC/AT's were chosen as a suitable computers for real time control of groups of equipment and measuring benches.

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BEAM EXTRACTION CONTROL SYSTEMS OF THE FAST-CYCLING SYNCHROTRON

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Abstract

A compact system controlling the extraction of different beams (gamma, electron, synchrotron radiation) in single and simultaneous operation modes at high electromagnetic disturbances level based on using one computer of IBM PC/AT type is described.

Introduction

Physical research program at the Yerevan synchrotron pursues the realization of the experiments generally with the use of the slow extraction of primary and secondary beams in single and simultaneous operation modes at 4.5 GeV energy with the 4-8 μs magnetic field top. The most complicated process of the extraction, requiring the precision tuning of the beam extraction devices and not having analog in the world is the mode of simultaneous beam guidance to the two internal targets, one of which is a thin crystal, the other one is of thick tungsten and is put in the neighbouring focusing interval of the synchrotron. At the same time it is necessary to provide a significant decrease of the beam pass factor through the thin target by screening from the particles, once passed through it by means of the thin target [1].

Due to the developed and described below the control system of the synchrotron extraction devices it was managed to increase the ratio of the pick of coherent bremsstrahlung radiation from the thin crystal target to the amorphous part almost 2.5-3 times with keeping unchanged the common requirements to the extracted beam parameters, that is to say to the stable uniformity and duration of the extraction, effectiveness of the extraction and so on.

Secondary beam extraction of the Yerevan synchrotron is based on the local disturbance of the orbit with using the additional electromagnetic coils of the guiding magnetic field. At the beam guidance simultaneously onto two internal targets there is also used a system of changing the betatron oscillation frequencies of the circulating particles with the help of the lenses set on the orbit. To realize the slow extraction of the primary beams to the vicinity of the nonlinear resonance of the third order the conventional system of magnetic elements (quadrupole and sextupole lenses; septum and bending magnets) is used. Magnetic elements and additional coils of the electromagnet are supplied by the current pulses of the complicated shape, produced by the resonance forming lines with the use of the thyristor switches. The tuning of the form and amplitude of the current pulses is realized by means of the face control of thyristor switches with the use of the synchronizing pulses from the synchrotron timer device. The control of the current pulse form and the intensity changes during the beam extraction is carried out by many pickups.

1. Architecture and the control system construction principles

The first control system of the synchrotron extraction device was based on the control computers EC1010 and EC1011 (Videoton firm, Hungary) [2]. But the lack of reliability in their work and the relatively expensive maintenance showed the necessity of replacing them by the modern computers. The computer PC/AT was chosen for that. It determined the architecture of the control system from the one hand and from the other the requirements of reliability and flexibility at high level of the electromagnetic noises were satisfied by having an intensive information flow, a large number of the control parameters and so on. That's why a mixed 3-level architecture of

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Instrumentation & Control System For PLS-IM-T 60 MeV LINAC

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Abstract

The PLS*IMT* is a 60 MeV LINAC as a preinjector for 2 GeV LINAC of PLS project. The instrumentation and control system have been designed under the institutional collaboration between the IHEP (Beijing, China) and POSTECH (Pohang, Korea). So far, the I&C system are being set up nowadays at the POSTECH of Pohang. This paper describes its major characteristics and present status.

I. Introduction

The Concept Design Research(CDR) of PLS 60 MeV LINAC has been completed in 1989. The construction of PLS 60 MeV started in July, 1991. The accelerator column and electron gun have been installed earlier. The gun pulser has been tested with 3.5A 2ns pulse width with success and Modulator, microwave system and I&C system will be set up soon. The commissioning of whole system would be completed around the end of this year or next spring.

The I&C system of PLS 60MeV is a compact and complete hierarchical distributed control system. Therefore it is small system and it includes all of the essential control structure and various beam monitor, high speed electronics modules etc. for LINAC operation.

II. System Structure

In a centralized control system, computer failure will cause a failure that will shut down the entire system. However, a distributed system is more costeffective and becomes easily modified.

According to the requirements of physics and our previous experience, and considering the entire budget, schedule of I&C of PLS 60MeV, we compared various structure of control system [1], and adopted the Intel BITBUS architecture. The major reasons are as follows:

* BITBUS distributed control system is a commercial product

* High performance microprocessor could be useful for local station.

* Powerful software support such as RMX286 and RMX51 are an excellent developing environment. The function that have to be explicitly coded can be greatly reduced by making system calls. A BITBUS drive can be run under the RMX286 which allows messages passing across the SBX interface on down the BITBUS network.

* More second source: We should consider the situation that developing this system is in China, and commissioning and maintenance is in Korea. So we must get these products easily from the market of both country.

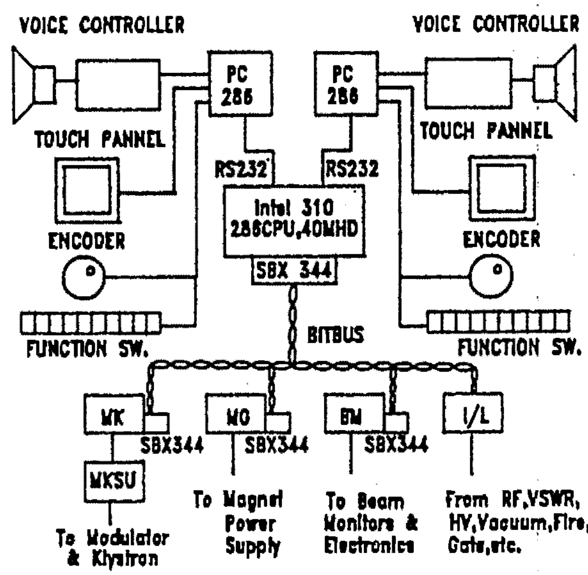

Fig.1 I&C archtecture for Preinjector of PLS

According to the considerations above, the system architecture is illustrated in Fig.1.

There are four stations linked with BITBUS network, each station has its own resource and tasks respectively. Those local stations are Modulator-Klystron Station(MK), Magnet power station(MG), Beam diagnostics station (BM) and Interlock station(IL).

In general, entire task are hierarchically managed. Each local station completes data acquisition and data control during the 5ms period. the details of MK local station

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Multi-Microprocessor Control of the Main Ring Magnet Power Supply of the 12 GeV KEK Proton Synchrotron

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Abstract

A general description of the computer control system of the KEK 12 GeV PS main ring magnet power supply is given, including its peripheral devices. The system consists of the main HIDIC-V90/25 CPU and of the input and output controllers HISEC-04M. The main CPU, supervised by UNIX, provides the man-machine interfacing and implements the repetitive control algorithm to correct for any magnet current deviation from reference. Two sub-CPU's are linked by a LAN and supported by a real time multi-task monitor. The output process controller distributes the control patterns to 16-bit DAC's, at 1.67 ms clock period in synchronism with the 3-phase ac line systems. The input controller logs the magnet current and voltage, via 16-bit ADC's at the same clock rate.

1.INTRODUCTION

The main ring magnet power supply consists of 10 twelve-pulse thyristor rectifiers with dc filters, of 2 reactive power compensators [1] with tuned ac harmonic filters [2] and of an analog and digital hybrid control system [3]. A schematic diagram of the power supply is given in Fig. 1. Fig.2 shows the principle layout of the hybrid control system. Eight rectifiers feed the bending magnets and the other two excite the horizontally and vertically focusing quadrupole magnets. Fine adjustment of the current at injection and of the ratio between currents of the bending and the quadupole magnets is required to tune the acceleration. The current of the quadrupole magnets must be tracked separately from the current of the bending magnets for precise Q-tuning and optimum beam acceleration.

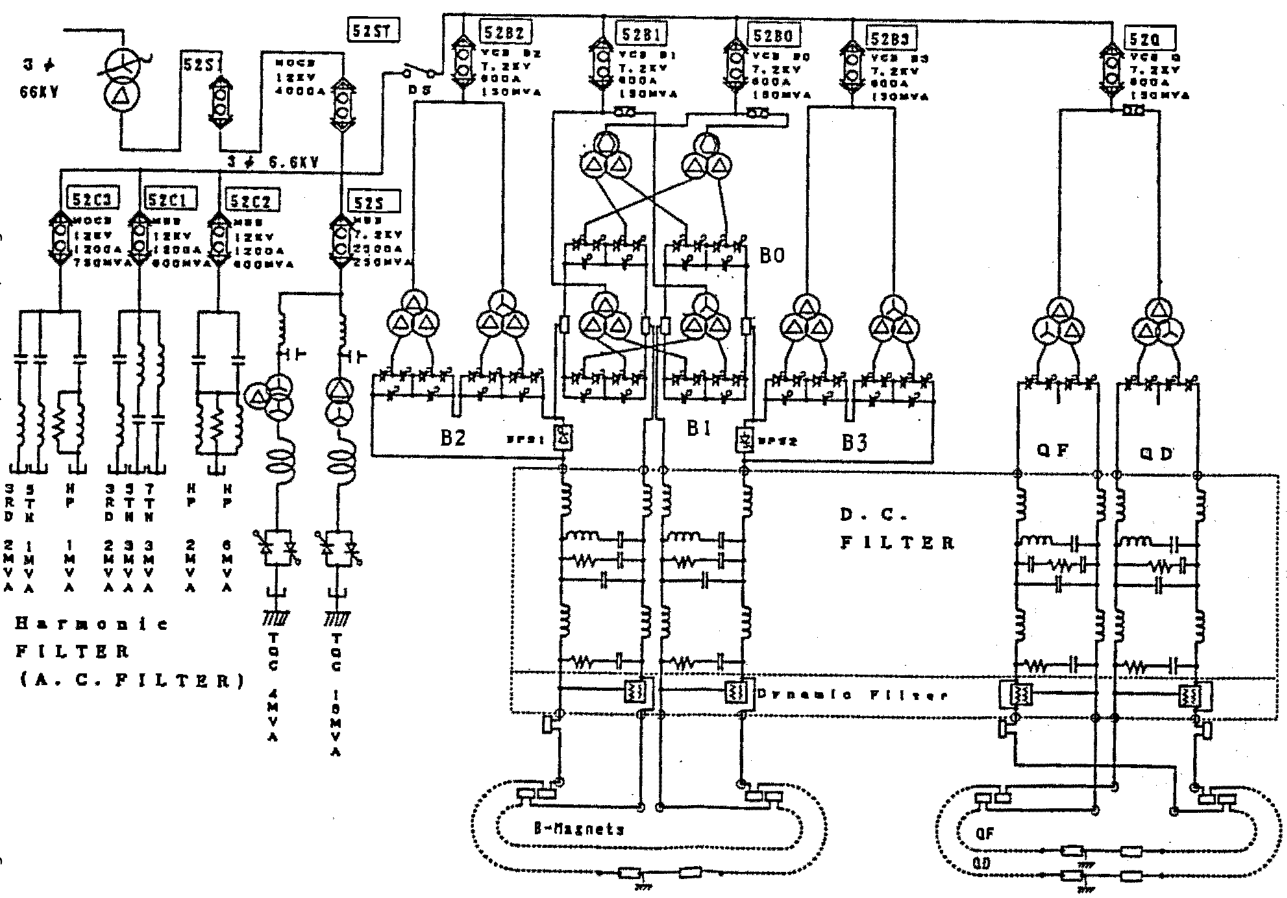

Fig.1 Schematic Diagram of the KEK 12 GeV PS Main Ring Power Supply.

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VME COMPUTER MONITORING SYSTEM OF KEK-PS FAST PULSED MAGNET CURRENTS AND BEAM INTENSITIES

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Abstract

For beam transfer from the KEK-PS Linac to the Booster synchrotron ring and from the Booster to the Main ring, many pulse magnets have been installed. It is very important for the machine operation to monitor the firing time, rising time and peak value of the pulsed magnet currents. It is also very important for magnet tuning to obtain good injection efficiency of the Booster and the Main ring, and to observe the last circulating bunched beam in the Booster as well as the first circulating in the Main. These magnet currents and beam intensity signals are digitized by a digital oscilloscope with signal multiplexers, and then shown on a graphic display screen of the console via a VME computer.

1. INTRODUCTION

There are many pulsed magnets and beam monitors which concern beam injection and extraction of the KEK-PS-Booster as well as beam injection of the Main ring. In order to tune the machines and to search trouble points, it is very important to display these signals using proper trigger timing. Because we must select a proper signal and trigger among many connectors and choose a proper time scale, voltage range and trigger level, only a few trained crew members had been able to observe the expected signals within a short time. By using signal multiplexers, a digital oscilloscope with GPIB and a VME computer system, however, we can now observe the expected signals without any great effort using a touch panel of a console desk in the PS-control room.

2. PURPOSE OF THIS SYSTEM AND REQUIRED SIGNALS

A. Observing pulsed magnet current

In order to observe the operating conditions of the pulsed magnets, the following magnet currents should be observed with proper time scale:

- For Booster Injection:
  - four Bump magnets in series
- For Booster Extraction:
  - Bump(#1,#2)
  - Septum(#1,#2)
  - Kicker(#1~#4)
- For Main Injection:
  - Septum(#1,#2)
  - Kicker(#1~#5)

B. Checking the magnets' firing timing

For beam transport from the Booster to the Main ring, just after firing the Booster extraction septums and carrying out time-matching of an RF bucket of the Booster ring with one of the Main ring, Booster extraction bumps are fired; after about 20μsec, four kickers are fired at the same time. After a transfer time from the Booster to the Main, firing of five Main injection kickers follows. In order to check these timing, it is convenient to display the concerning magnet currents and a bunched beam intensity with a "mountain view"*.

*When you observe rapid changing figures as a kicker current and a fast beam intensity in the control room, the figure deterioration through a long co-axial cable becomes problem. We have re-shaped the deteriorated figure to the original by the "equalizer" made by Dr.S.Ninomiya. We would like to acknowledge him for his offering of his instrument.

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Magnet Power Supply and Beam Line Control for a Secondary Beam Line K6

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Abstract

K6 is a secondary separated-beam line with momentum range up to 2.0 GeV/c in the north experimental hall at the KEK 12 GeV Proton Synchrotron (KEK-PS). On the construction, newly developed magnet power supplies (MPSs), in each of them a microprocessor is embedded, are introduced. The features of the MPS are as follows:
1, The MPS is connected to an upper-level beam line controller (BLC) by GPIB highway for exchanging simple messages.
2, All the operations of the MPS are supervised by the microprocessor, which has its individual parameters and fault messages. It reduces the load of the upper-level controller.
3, The MPS has functions to inspect itself and to report the result. It saves much time and labor of maintenance.

INTRODUCTION

On the KEK-PS site, there are two experimental halls for high energy physics experiments. The one is the East experimental hall (E-hall), that has been servicing since 1977. The other is the North experimental hall (N-hall) built in 1990, where the construction of the new beam line K6 construction is under going.

In N-hall, the beam lines were designed for high-intensity proton beams against high radiation field. The R&D for the beam line components has made during the last few years. The design of the magnets and vacuum system were reported in [1]. On the other hand, magnet power supply (MPS) and control system have also been developing [2].

On the construction of the K6 beam line, newly developed MPSs were introduced. Each MPS has a microprocessor, ADC(analog to digital converter), DACs (digital to analog converter), relay I/O(input and output), and GPIB(IEEE-488) interface. The digital processing unit i.e. magnet power supply controller (PSC) is incorporated into the MPS to have functions; ON, OFF, reset of interlocks circuit, polarity switch, current/ voltage control mode, current setting with appropriate speed, and checking the health of the MPS without help of upper-level beam line controller. These functions are invoked by a simple message, for example; current setting message; "A 1234.0" means to set output-current to 1234.0 ampere. This message is sent to MPS from BLC through a single coaxial cable; GPIB highway.

These design concepts were reported several years ago, [3], [4]. Though effective, those design concepts have been applied to few devices on the accelerator field up to present.

We introduced this design concept in to beam line control system, and developed MPS. Now we are saving cost, time, and trouble.

This paper report this MPS's PSC and beam line control for K6. The details on soft program and hardware will be reported elsewhere.[5]

POWER SUPPLY CONTROLLER (PSC)

Hardware

PSC consists of five boards (STD: IEEE-961):

(1) CPU board: Z-80, GPIB communication interface.

(2) DAC board: 16-bit DAC, for reference voltage.

(3) ADC board: 16-bit ADC, for monitoring DCCT (output current).

(4) ADC board: 12-bit ADC, 16-channel multiplexer.
This board is used for monitoring the following values:
1, Reference voltage (16-bit DAC).
2, MPS's DC output voltage
3, MPS's output voltage for monitoring Wave Form.
4, MPS's AC input current .
5, Input voltage of firing module.
6, Seven points on low-voltage power supplies.

(5) Relay I/O board: for control and monitor.
The control points are:
1, ON/OFF
2, Reset of interlock logic.
3, Polarity switch.
4, Regulation mode (voltage or current).
5, Remote or Local

Input points for monitoring status are:
1, Control power ON/OFF.
2, Remote/ Local.
3, Main switch, ON/OFF.
4, Polarity +/-.

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SPECIFIC BEAM DELIVERY SYSTEM OF MEDICAL ACCELERATOR HIMAC

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Abstract

A specific beam delivery system for radiation therapy in HIMAC is being designed. This report describes an outline of the beam delivery control system and its operation.

I. INTRODUCTION

HIMAC is a heavy ion accelerator facility designed for radiation therapy[1]. Beam delivery system of HIMAC is very specific and different from the ordinary facilities for experiments of general physics. The treatment control system for irradiation of patients is closely linked with operation of accelerator and beam transport. We report an overall idea of HIMAC beam delivery system and its operation for radiotherapy.

II. CLINICAL REQUIREMENTS

The clinical requirements for radiation therapy are described as follows.

1) At the end of irradiation, three dimensional dose distribution at the tumor volume in the patient must be achieved with an error of less than a few % compared to the precalculation of the dose distribution by the physician. Above all, overdose to the patient must be absolutely avoided.

The tumor of the patient as a target is set at the beam iso-center with an accuracy of less than 1mm. In case of the abdominal organ as the target, it is subject to move by breathing, and the margin of irradiated field should be considered in the treatment planning. Since the shape, volume and position of patient's target and the planned dose distribution are different for each patient, setting of many kinds of devices in the beam port varies at the time of each irradiation. The size of most treatment is satisfactory within a maximum field of 22cm in diameter which is based on clinical experiences at NIRS. On the other hand, small fields such as less than 1cm are often required. Hence, devices of beam port must be accurately adapted for wide range of field size.

2) Irradiation time per patient must be less than a few minutes. The reason is that the patient is immobilized on the couch by the shell or capsule, and immobilization of longer time gives much stress to the patient with illness. Now we are estimating that it takes about ten minutes to set a patient for positioning on the couch. Therefore, treatment time that a patient stays in the treatment room is about fifteen minutes. HIMAC has two synchrotron rings and three treatment rooms (Fig. 1). In the room B, horizontal and vertical beams can be utilized at the same time, and the room A and the room C have the vertical and the horizontal beam course respectively. Accordingly, two beams are delivered to four beam ports alternately. The course of each beam is changed at interval of about ten minutes, and the beam should be immediatly adjusted in compliance with medical requirement for each patient. To realize such a rapid change, all magnets along the beam transport lines are actuated by corresponding treatment schedule and the beam course can be changed by setting only one switching magnet in HEBT(high energy beam transport) line. For these reason, switching magnet must have accurate reproducible setting of field strength and high stability.

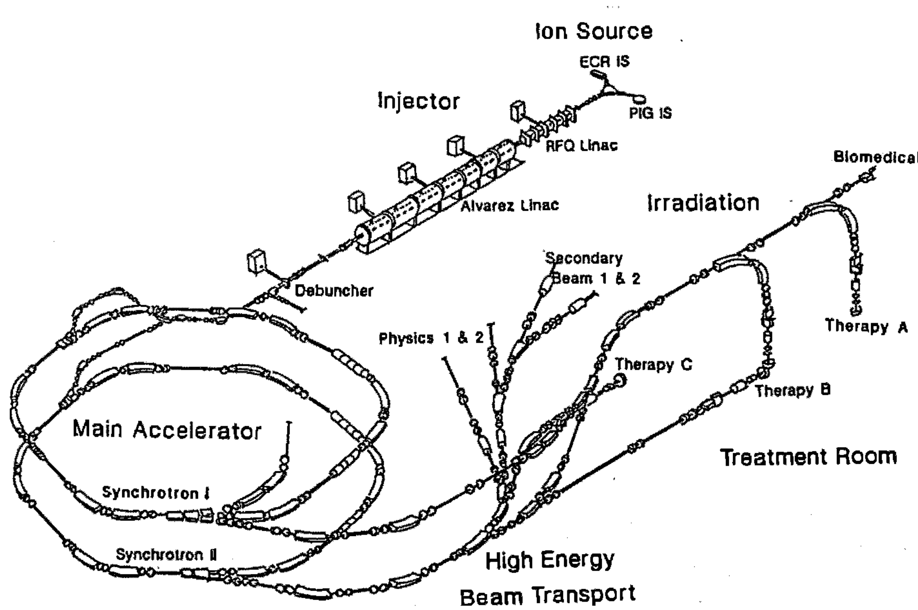

Fig. 1 A schematic view of accelerators and beam lines

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A CONTROL SYSTEM FOR A FREE ELECTRON LASER EXPERIMENT

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Abstract

The general layout of a control and data acquisition system for a Free Electron Laser experiment will be discussed. Some general considerations about the requirements and the architecture of the whole system will be developed.

I. INTRODUCTION

The aim of the ELFA (Electron Laser Facility) experiment is to study the physics of a single pass FEL amplifier operating in the high gain Compton regime using a short electron pulse beam. The experimental purpose is the production of high peak power (0.3-1 GW) of microwave radiation, with a basic wavelength of λr=3 mm, and the possibility of tuning from λ = 1 cm to λr=0.1 mm. In order to achieve this goal an electron beam of very high current (400 A) in short pulses (6 cm) and with a maximum energy around 10 MeV will be injected into the wiggler midplane.

The accelerator consists of two sections: a photocathode injector providing a 3.5 MeV beam and a superconducting LEP II module to increase the energy up to 10 MeV. The wiggler will be a composite one, consisting of two coupled sections: the first part made with an hybrid structure (iron poles and permanent magnets) and a second part with an e.m. structure. A complete review of the project is given in [1] and a general layout of the experiment is showed in fig. 1.

The ELFA project has been funded by INFN and a lot of work has been done in order to define the conceptual design of the major components and to deeply investigate the FEL physics.

II. BASIC CONTROL PHILOSOPHY

A preliminary analysis of the characteristics required to the control system for ELFA pointed out the following items:

- ELFA needs both a control and a data acquisition system. Since ELFA is an experiment itself it is mandatory to have a complete data acquisition system for the measurements which have been planned to verify the basic ideas of the project. It is not possible to separate machine operations from physicist work. The two systems must be designed at the same time, sharing , as much as possible, the same philosophy and allowing an easy exchange of data.

- ELFA would take at least one year to "freeze" the characteristics of the major components. Nevertheless before of these period the control philosophy has to be fully developed and tested, in order to be an intrinsic feature of every component. A control system must play a central role in the whole design of a machine, to be really effective and to justify its budget requirements,. It is an old-fashion, money-wasting philosophy that one which consider the control system as just an "add-on" of the machine. In this way the control equipments just duplicate features already present and does not provide any improvement in performances. At the same careful attention has to be paid in order to evaluate the trend of development of computer technology. One has to balance today requirements and needs, with tomorrow availability and costs. This is more difficult to do since the different growth rates of the two basic components of a computer system : hardware and software.

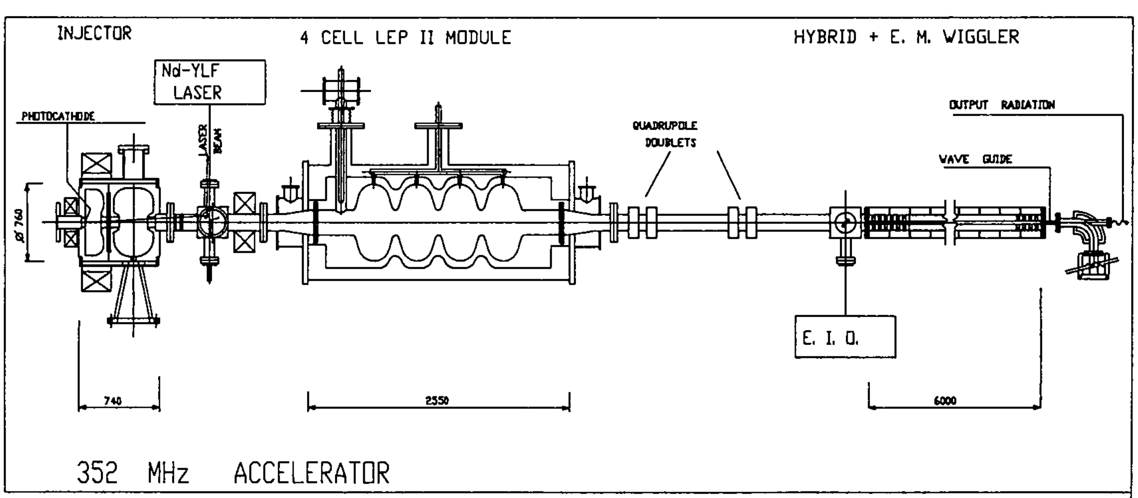

Fig.1 -General layout of the ELFA experiment

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Control System for JAERI Free Electron Laser

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Abstract

A control system comprising of the personal computers network and the CAMAC stations for the JAERI Free Electron Laser is designed and is in the development stage. It controls the equipment and analyzes the electron and optical beam experiments. The concept and the prototype of the control system are described.

I. Introduction

The Free Electron Laser (FEL) facility, SCARLET (SuperConducting Accelerator for Research of Light Emission at Tokai), is now under construction at JAERI[1–3]. It is a first step of the FEL program and the aim is the R&D of the superconducting accelerator (SCA) based FEL system in 10–50 μm range. The SCA is employed due to the suitability for the cw operation in the second phase of the project. The layout is shown in figure 1 and the main characteristics are described in table 1.

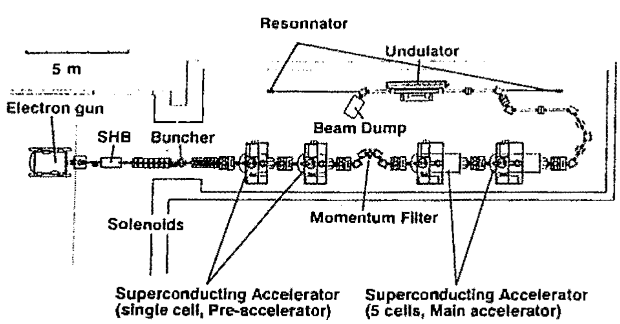

Figure 1. Plan view of the accelerator room of the JAERI free electron laser facility.

The accelerator itself is a small size with less than 20 m length, however, it would be expanded to 60 m in the second phase. In the design of the control system of the JAERI FEL, which will be also used in the next phase, the requirements were posed as:

1. Flexibility for evolving the system,
2. Reliability of hardware and software,
3. User interface for operator console,
4. Integrity of control and simulation,
5. Distributed control for fast response.

Table 1
Main characteristics of JAERI FEL
(first phase)

ITEM	SPECIFICATION
Electron Energy	14 – 23 MeV
Energy Spread	< 0.2 %
Peak Current	> 10 A
Pulse Width	40 ps
Repetition	10.4 MHz
Undulator Pitch	≈ 3 cm
Laser Wavelength	10 – 50 μm
Laser Peak Power	1 MW

II. Hardware Architecture

In this project, the flexibility has the highest priority to accommodate the frequent change and upgrade of the hardware devices in the development stage and at the next phase. The devices in the facility are divided into three subgroups: (1) the injector section (electron gun, sub–harmonic buncher, buncher, and injection beam transport line), (2) the accelerator section (superconducting cavities, rf power supply, refrigerators, momentum filter, achromatic bend line) and (3) the optics instruments (undulator, mirrors, optical detectors). They are well isolated by the locations and their functions.

Each subgroup is controlled by a local unit equipped with:

- a 32–bit personal computer (NEC PC 9801:cpu i80386 16/20MHz, 3–5 MB RAM, 14–in CRT) with minimal peripherals to control the local unit alone,
- a dedicated CAMAC crate system with parallel bus crate controller, which contains analog i/o, digital i/o and GPIB interface modules,
- an Ethernet interface.

The main console unit consists of two personal computers, one is used to control the tasks in the network and another is used to analyze and display the acquired data or on–line processed results in a 21–in CRT. These are connected by Ethernet and SCSI

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Control Software for the ESO VLT

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Abstract

The Very Large Telescope (VLT) project of ESO consists of an array of four optical telescopes of 8m diameter, to be installed at a new site in the Atacama desert in Chile starting in 1995.

The control software is completely distributed, being based on LANs interconnecting microprocessors and workstations, where several users and operators will be active at the same time.

Microprocessors are used in a variety of control functions, including the active control of the shape of the main mirror and compensation for atmospheric turbulence. Dedicated links and antennas are planned for direct communication and remote observation from various European centers.

The main concepts and novelties of the software design are explained.

I. THE VLT PROJECT

A Main characteristics

The VLT project has been initiated with the aim to provide European astronomers with a ground based telescope of larger size than those presently available [1].

The VLT concept consists of an array of four identical main telescopes, each having a thin monolithic mirror of 8m diameter. This gives an equivalent total size of 16m, when the four telescopes are used together, which shall be the largest size available on ground telescopes at the end of the 90s. The large size of the array will allow a very high angular resolution (the possibility to resolve details).

Each main telescope has an Alt-Azimuthal mount and is equipped with instruments at the two Nasmyth foci, Cassegrain focus and Coudé focus.

The four main telescopes can be used independently, or in several combined modes. One of the combined modes is the incoherent beam combination in a combined Coudé laboratory.

The other combined modes foresee coherent beam combination in an interferometric laboratory. In this case the use of two or more auxiliary telescopes of 1.8m diameter is also foreseen. These should be moveable on tracks. Optical path differences will be compensated with the use of delay lines and the optical beams are brought to interfere. Astronomical images can then be reconstructed starting from the interference patterns.

The use of a chopping secondary mirror has been proposed.

The VLT site is the Paranal mountain in northern Chile, in the Atacama desert at an altitude of 2700m.

Figure 1 shows the telescope layout foreseen for the top of mount Paranal. The first telescope is due to be installed at the end of 1995, with each following telescope being installed at time intervals of one year.

The whole VLT program including instrumentation will be concluded some years later. This gives a very long timespan for the installation of the VLT and of the control system in particular.

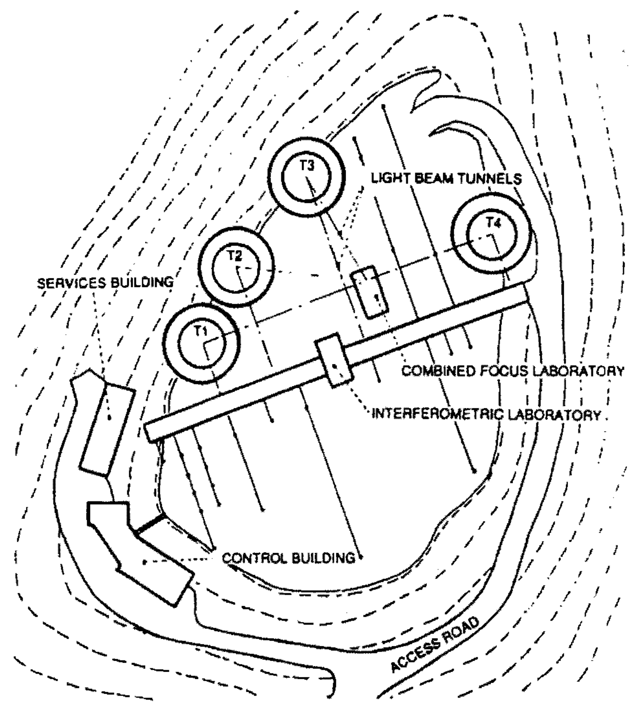

Figure 1: VLT observatory

B Special aspects

Special aspects of the VLT telescope with respect to other telescopes are:

- system distribution

  This is implied by the fact that the VLT is an array of four telescopes.

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Distributed Control And Data Acquisition For The EUROGAM Gamma Ray Spectrometer

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Abstract

EUROGAM is an Anglo/French Gamma Ray Detector which will alternate between the Tandem Van der Graaf at Daresbury and the Vivitron at Strasbourg. Because of the need to conform to the standards of Laboratories in two different countries, and the very sensitive nature of electronics for Germanium Gamma Ray telescopes, the newly emerging VXIbus (VMEbus EXtensions for Instrumentation) was chosen as the basis for control and data acquisition. This entailed a major programme of development for both the signal processing front end modules for Germanium and Bismuth Germanate detectors, and also for the hardware and software management of resources from within the VXI environment. The paper will concentrate mainly on the latter areas.

I. INTRODUCTION

EUROGAM is a high resolution gamma-ray detector which is being constructed to answer the many exciting questions raised through recent discoveries in Nuclear Physics. Phase I of the EUROGAM array provides 45 Germanium (Ge) detectors with surrounding Bismuth Germanate (BGO) detectors being used to provide the suppression shields. A second phase is planned which will provide a 70 detector system. EUROGAM is a joint development project between Institut National de Physique Nucléaire et de Physique les Particules (IN2P3), France, and the Science and Engineering Research Council (SERC), UK. The array is expected to come into operation at the Nuclear Structure Facility at Daresbury Laboratory, UK, early in 1992 and will run for one year following which it will be transferred to France to operate on the new Vivitron accelerator which is being commissioned at Centre de Recherches Nucléaire, Strasbourg (CRNS).

II. TECHNOLOGY

To provide data acquisition, control and monitoring functions for EUROGAM, a mixed solution based on VXI, VME and UNIX workstations has been chosen with the overall system structure being arranged in a distributed computing architecture. Figure 1 shows the layout of the system and its component parts.

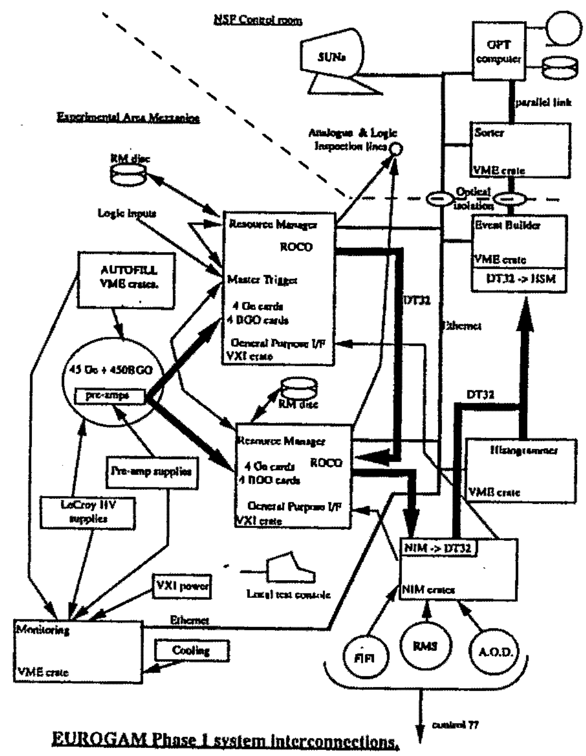

FIGURE 1.

VXI is used to front-end the system and has enough electric and magnetic shielding to allow the treatment of analogue signals to very low noise levels This permits a highly integrated approach to be taken in the electronics units designed for the processing of pulses from detector channels. VXI also minimises the inter-unit cable connections required and hence increases reliability. VXI also provides a full implementation of a 32 bit VME bus for general control of cards in the crate, read-out capability and multi-master processor access. The enhanced features contained in the VXI standard

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A Control System of the Nobeyama Millimeter Array

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Abstract

We have developed a control system of the Nobeyama Millimeter Array which is a radio interferometer for astronomical observations at millimeter wavelengths. The system consists of three sub-systems (MANAGER, ENGINE, and STATUS CONTROLLER). Observers conduct their observations with MANAGER sub-system, which run on a UNIX workstation. ENGINE is a rigid system on an IBM compatible mainframe. It controls the accurate tracking of astronomical radio objects, and acquires a large amount of observed data from a receiver backend. STATUS CONTROLLER consists of several personal computers which control and monitor the receiver system. These sub-systems are connected with an ethernet.

Figure 1: The Nobeyama Millimeter Array.

1 INTRODUCTION

The Nobeyama Millimeter Array (NMA) [1] is a radio interferometer for astronomical observations (Figure 1). The main purpose of the NMA is the high spatial resolution imaging of celestial objects at millimeter wavelengths.

The array has five 10-m diameter antennas which can be moved to various stations along two rail tracks of about 600 m. Averaged surface accuracy for five antennas is 71 μm rms. Each antenna has an Alt-Azimutial mount and is equipped with SIS receivers [2] at 2.6 mm and 2.0 mm wavelengths which contain important molecular spectral lines. The maximum spatial resolution at 2.6 mm wavelength is about $1''$. The receiver backend is a 320 MHz FFT spectro-correlator with 1024 frequency channels per correlation, called as the Nobeyama FX [3].

The most important requirement for a control system of such an interferometer for astronomical observations is to track celestial objects accurately [4]. For an interferometer, the tracking control is much more complicated than that for a single dish telescope. To satisfy this requirement, we constructed a centralized control system for the NMA on an IBM compatible mainframe [5]. However, since the softwares of the system were very rigid, there were some drawbacks in it.

To overcome these drawbacks, we have developed a new control system for the NMA. It is a distributed system, based on a UNIX workstation, an IBM compatible mainframe, and personal computers connected with an ethernet. In this report, we will describe the concept and the structure of the new system.

2 CONTROL FOR OBSERVATIONS WITH THE NMA

2.1 Tracking

Normal observing mode of this array is aperture synthesis[6]. Figure 2 shows a schematic diagram of aperture synthesis observation with two element radio interferometer. A correlator multiplies two radio signals from each antenna and averages the product. When antenna tracking to a celestial object and compensation of optical path difference between two antennas (delay tracking) are done accurately, the correlator output is equal to a spatial Fourier component of the brightness distribution at a projected baseline (u, v). After the synthesis observations at many different baselines, the brightness distribution can be estimated with inverse Fourier transform.

As shown in Figure 3, we use a heterodyne system for a frontend receiver and frequency of the input signal to the delay tracking system is lower than receiving frequency.

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Present Status of the JT-60 Control System

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Abstract

The present status of the control system for a large fusion device of the JT-60 upgrade tokamak is reported including its original design concept, the progress of the system in the past five-year operation and modification for the upgrade. The control system has the features of hierarchical structure, computer control, adoption of CAMAC interfaces and protective interlock by both software and hard-wired systems. Plant monitoring and control are performed by an efficient data communication via CAMAC highways. Sequential discharge control of is executed by a combination of computers and a timing system. A plasma feedback control system with fast 32-bit microprocessors and a man/machine interface with modern workstations have been newly developed for the operation of the JT-60 upgrade.

1. Introduction

The JT-60 tokamak is a large scale fusion experimental device for the study of magnetically confined plasmas near the thermal break-even condition. Since the first plasma obtained in April 1985, studies on impurity and particle control, confinement of high-power heated plasmas and steady state operation by radio-frequency wave current drive and production of the bootstrap current discharges were performed. The JT-60 tokamak has been upgraded in order to push forward these fusion researches conducted in the past five-year operation [1]. In the JT-60 upgrade (JT-60U) we can perform deuterium discharges with plasma current up to 6 MA and additional heating power of 50 MW. Throughout these investigations we intend to obtain physical and technological databases for the next-step machines.

This paper reports the present status of the JT-60 control system including its original design concepts, progress of the system in the past five-year operation and modification for the upgrade.

2. Requirements and Design Philosophy

Since the JT-60 tokamak is a large-scale device with respect to the number of components, their occupied space, the amount of electric power consumption, etc. Since intrinsically unstable plasmas are produced and maintained, the control system is required to have high reliability and high speed. Besides these features it has to possess the characteristics of flexibility, expansibility and safety. Hence, the JT-60 control system was designed and fabricated with the following features [2]:

(1) Hierarchical structure

JT-60U consists of more than ten subsystems such as a vacuum pumping system, magnet power supplies and plasma heating apparatus. These subsystems have to be separately operated in their preparatory stages before plasma operation. Moreover, they have to be organized into one system to perform plasma operation. Hence, the JT-60 control system has hierarchical structure of its central control system named ZENKEI and subsystem controllers.

(2) Computer control

Computer control was introduced for the operation of the JT-60 tokamak. Eight minicomputers and about a hundred microcomputers are used for a wide variety of control functions from fast feedback control of plasma discharge to handling of a large amount of monitoring and control data. In addition to 16-bit computers in the original control system, advanced 32-bit microprocessors and workstations have been newly introduced in the control system.

(3) CAMAC interfaces

Since fabrication for each subsystem was contracted to industry separately, various kinds of standards for both hardware and software were decided as JT-60 standards at Japan Atomic Energy Research Institute (JAERI). CAMAC standards were adopted for input/output signals from sensors /to actuators and for data transfer between the computers.

(4) Protective interlock by both software and hard-wired systems

The safety philosophy was established by taking into account certain key requirements in the design of the JT-60 control system. One of the most important requirements is personnel safety. This stems from use of high electric voltage, high magnetic field and possible radiation in the JT-60 tokamak. Hence, the protective interlock system with hard-wired relay logic backs up the computer system from the view point of reliability and safety. Moreover, the concept of precaution and protection was introduced in the system design.

3. System Configuration

3.1 Control Configuration

The control concept of the JT-60 tokamak can be classified into two categories. One is control for plant control and monitoring and the other is for plasma control via actuators used for tokamak discharge.

The concept of plant support control is similar to that in other large-scale facilities such as manufacturing and power

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Conceptual Design of Centralized Control System for LHD

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Abstract

A centralized control system for a fusion experimental machine is discussed. A configuration whereby a number of complete and uniform local systems are controlled by a central computer, a timer and an interlock system is appropriate for the control system of the Large Helical Device(LHD). A connection among local systems can be made by Ethernet, because a faster transmission of control data is processed by a specific system.

I. INTRODUCTION

The National Institute for Fusion Science(NIFS) was established by The Ministry of Education, Science and Culture in 1989 to integrate all of the inter-university collaboration in Japan for nuclear fusion research. The new and main project of Large Helical Device(LHD)[1] at NIFS was approved during the 1990 Japanese-fiscal-year(JFY). The LHD system presently under construction at the new site of NIFS in Toki-city, Gifu-prefecture, will be completed in the 1996JFY[2].

The LHD system, with superconducting coils, will be the first machine which can sustain the stationary magnetic field composing nested magnetic surfaces. A magnetic surface is generated from a combination of the toroidal magnetic field and the helical magnetic field. It is the outermost magnetic surface, which determines the confinement area. A ring plasma with a major radius 3.75m and an averaged radius of cross-section 0.65m is confined. A schematic view of LHD is given in Fig.1. The magnetic field is generated by a pair of superconducting helical coils and three pairs of superconducting poloidal coils. The stored magnetic energy in a typical 4T operation (the strength of the average toroidal magnetic field at the plasma center) is 1.63GJ. The initial plasma is usually produced by radio-frequency(RF) power at the electron-cyclotron-resonance(ECR). The plasma is subsequently heated by arbitrary use of 20MW neutral beam injection(NBI), 10MW ECR heating and 9MW ion-cyclotron-range-of-frequency(ICRF) heating.

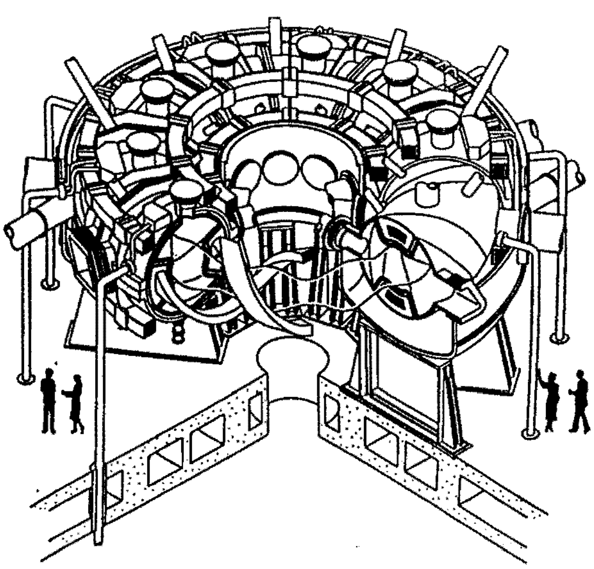

Fig.1 Schematic view of The Large Helical Device

The control system for LHD operation must be designed to ensure the safety of the whole LHD system which contains sensitive electronics as well as rough facilities handling large stored energy, high power, high voltage and high current within the same environment. It also has to manage an efficient performance of the plasma experiment. There are some distinctive characteristics in the control of such a large fusion machine still in an experimental phase.

The reliability is the most important factor in the present system. Since the power used is sufficient to cause fatal damage, the safety must be garenteed, including the case of an accident. A choice of reliable materials and an additional backup can ensure this reliability, but finally it is related to the available cost. Here, we consider only the logical reliability of the control system.

The flexibility of a configurational setup is very important for a machine in an experimental phase. Besides replacement, new types of facilities should be easily added to the system. Thus, the control system should be flexible.

There are various time scales to be controlled within. The real-time control in a pulsed plasma experiment is usually too fast to be treated by an operator's manipulation. Hence, the control of the plasma by an operator is made through pre-programming. Thus, the function of fast control necessary for plasma operation should be excluded from the role of a global controller. If necessary, such a function must be treated in a specific controller.

The pulsed characteristics of the plasma experiment, on the other hand, make the target very clear and simple. All facilities are operated in order to produce a high-temperature, high-density and well-confined plasma.

The last requirement is a possible local operation of some part of the facilities. When such an operation is demanded, global safety must be assured by the central controller.

Considering the characteristics of the LHD operation, we have discussed the conceptual design of the centralized control, which can more easily establish a logical relation between various manipulations. By the way, the data acquisition is closely related to the machine operation. However, the transfer of the vast plasma data from the data acquisition system to the control system is not necessary. Instead, a small amount of diagnostics signal will be directly provided to the local controller which needs the signal for the control. The diagnostics are loosely coupled to the central control system.

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STATUS OF LHD CONTROL SYSTEM DESIGN

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Abstract

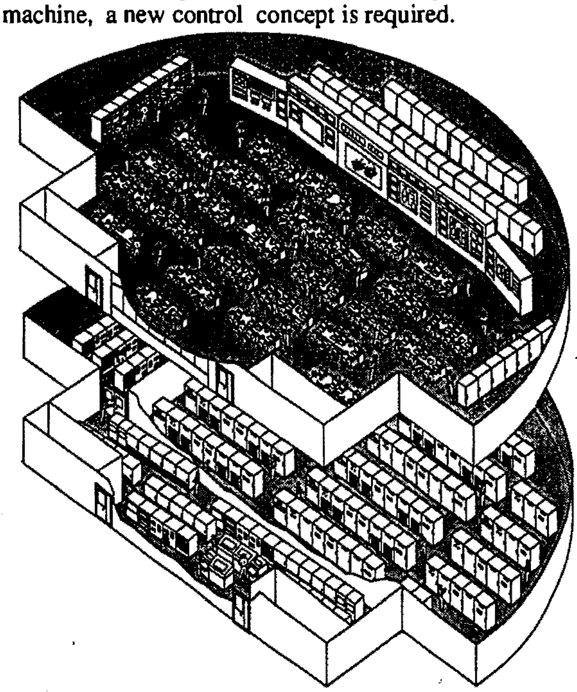
The present status of LHD (Large Helical Device) control system design is described, emphasizing on the plasma operation modes, the architecture of the LHD control system, the real-time plasma feedback system with PID or Fuzzy controllers and the construction schedule of the LHD control system. The conceptual and detailed designs are under way taking flexible and reliable operations for physics experiments into account.

I. INTRODUCTION

The Large Helical Device (LHD) fusion system [1-3] using 1.6 GJ superconducting (SC) magnet is now under construction and its plasma experiments will be started in April, 1997. For this purpose, a new national institute (National Institute for Fusion Science) was established in May,1989, and a new site (Toki city; one-hour drive from the present site in Nagoya) were prepared for these experiments. The main objectives of the LHD project are

(1) the study of the behavior of high temperature / high density plasmas using helical torus device for comprehensive understanding of toroidal plasmas, and
(2) the exploration of the prospect to the steady-state helical system reactor.

The major plasma radius of LHD is 3.9 m , and the magnetic field strength is 3 Tesla (4 Tesla in the second experimental phase), which is the largest SC fusion machine now under construction. To keep flexible and reliable operations of this SC machine, a new control concept is required.



In this paper, the present status of the control system for operations and experiments of the LHD system is presented.

II. LHD MACHINE DESIGN AND CONTROL CONCEPT

The LHD system consists of one pair of SC helical coils, three pairs of SC poloidal coils, plasma vacuum vessel, cryostat, vacuum pumping system, electric power supplies, plasma production system, liquid helium refrigerator, three (NBI, ECH, ICRF) plasma heating systems, many plasma diagnostic systems and so on. All these equipments should be monitored and controlled mainly from the LHD Control Building. Especially, the control system should be flexible as a experimental machine and reliable as a large plant.

In contrast to present helical devices, the LHD is characterized by the steady-state operation using superconducting helical coils and the built-in divertor, which requires the elaborate control scheme for operational safety and the new plasma feedback system for experimental flexibility.

These LHD machine and central control systems are schematically shown in Fig.1.

III. LHD OPERATION SCENARIOS

The LHD machine operation is divided into three modes; all shut-down mode, facility operation mode and experiment mode. The experiment mode consists of the SC magnet operation mode and the plasma experiment mode (Fig.2). These modes are defined for clarifying the personnel entrance permission, magnetic field hazard and possible radiation exposure. Aside from software interlocks, the hardware interlock logic should be determined independent of these modes.

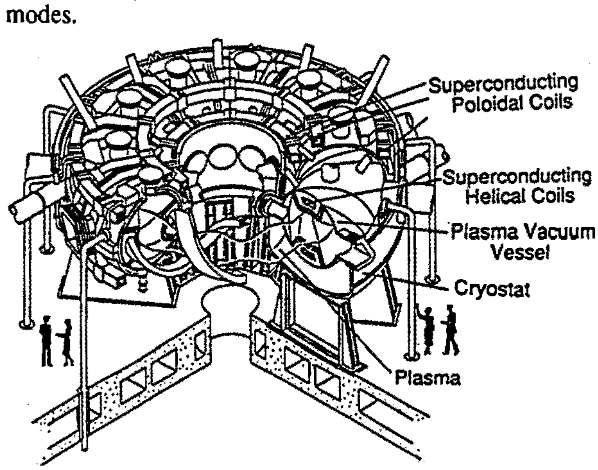


Figure 1 Schematicdrawings of LHD machine (right) and its control system (left).

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Control and Monitoring System Design Study for the UNK Experimental Setups

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Abstract

At present a number of experimental setups for the new UNK project are under construction. A common approach to the architecture of control/DAQ/trigger systems will be used in the development of electronics for all these detectors. The system analysis and design group has been formed for this purpose. The group activity is aimed at the development of such unified system. The group has started with control and monitoring system as one of the most important parts and the environment for the DAQ/trigger systems. The group activity status report is presented.

1. Introduction

The construction of several experimental setups is planned in the frame of the new UNK project at the Institute for High Energy Physics (Protvino) [1-4]. The size and complexity of these detectors is by an order of magnitude bigger as compared with those at the existing proton synchrotron. Table 1 shows the number of channels, event size and readout event rate for old and new (proposal) experiments.

TABLE 1

Exper.	Number of ch. $*10^3$	Event size (kbyte)	Event rate (Hz)
FODS-2	1	0.1	100
PROZA	1.5	0.5	250
SPHINX	25	1.5	100
VES	13	1	1000
NEPTUN	100	25-50	1000
GLUON	13	3	500
MPS	80	25-100	600
MMS	60	15-20	50-100

The general requirements to the electronics for the detectors have been formulated in the technical proposals. The electronics will be developed both at IHEP and at other institutes and organizations who take part in the detector preparation. The use of industry electronics is also foreseen. Such a distributed method of the development requires management and technical coordination when designing the electronics. A working group for the preliminary study of the design approaches and electronics architecture has been formed at IHEP.

2. Design Approach

At the beginning it was decided to choose the approach for the design of the electronics for different experimental setups, namely: to use specialized electronics designed for the specific experimental setups, or to use unified electronics adapted for a specific experimental setup. Both of them have well-known advantages and disadvantages. The choice is defined by the size and complexity of the detector, available funding and manpower, time schedule and so on. For the experimental setups at UNK it is possible to note the following points:

- experimental setups for the UNK are constructed practically at the same time,
- IHEP will participate in the design of the electronics for several (or all) experiments,
- the preliminary analysis of the electronics requirements for different experiments shows the existence of common functional elements.

With an account of the experience in using unified electronics for the experimental setups at the existing accelerator it seems reasonable to use the second approach for the electronics design at UNK.

As a second step the number of points to be studied at this preliminary stage have been defined with the aim to make some recommendation for the following investigations:

- standard modular unified architectures of the electronics for the experimental setups divided by the numbers of functional subsystems and levels with the definition of an unified interfaces,
- more detailed definition of this general architecture with the standard implementation of some parts of the system and possibilities of adapting these parts to the specific demands of the experimental setup,
- standard framework of the electronics development (tools, test setups management and so on),
- existing experience at IHEP in these areas.

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Hard- and Software for Measurement and Control of the Pulse Thermonuclear Installation

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Abstract

This paper describes control and measuring systems of the pulse thermonuclear installation "Angara-5". The "Angara-5" operates in a monopulse mode. It takes a long time to prepare the installation to the work shot . The main information flow about the installation output parameters and the target processes comes for 10^{-7}-10^{-8} sec. The measuring-control equipment has a multi-level hierarchy structure where the lower level is local systems controlled by own computers. Measuring systems contain waveform digitizers different types. The supervisor console system realizes the communications with the local systems, as well as the data acquisition, processing and storage. Hardware and software structures are given. Careful equipment shielding and grounding have provided level of noise 30 mV. Fast signals processing features are discussed.

I. INTRODUCTION

High power pulse generators had been using at first as accelerators of high current electron beams [1], lately have founded use as a driver technology for inertial confinement fusion experiments. Such generator can produce electromagnetic pulses with power 10^{13} - 10^{14} W and duration < 10^{-7}sec on load. Type of load is determined by experimentally program taken place at the installation. High voltage diodes producing intense ion beams are used as load at some experiments. Beams energy has been transporting on thermonuclear target [2]. Gas jets or liners different types are used as load at other experiments. In this case ions of load are accelerated to axis by means magnetic field of current through load [3]. It's necessary to note next features of such installations that determine structure of control and measuring systems:

-small duration of processes in installation after start (~10^{-6} sec). It excepts possibility of control at regime "on line" and requires application of fast analog-to-digital converters with buffer memory,

-seldom work starts of installation (few starts in day) make easier requires to systems of before-starting preparation and to data processing rate after shot. It's allows to design systems on base interfaces like CAMAC,

-high risetime of currents and voltages (~10^{14} V/sec, A/sec) provoke high level electromagnetic noise and requires the special design on electromagnetic compatibility of equipment.

Such installations are specific systems and requires design the special hard-software for effective working.

This paper describes the realization experience of control and measuring systems on the pulse thermonuclear installation "ANGARA-5" [4]. The installation consists of 8 modules worked synchronously on common load. Parameters of installation ($U=1.5$MV, $I=4$MA, $T=10^{-7}$ sec) allow to provide a different experiments on thermonuclear targets heating.

II. HARDWARE

Hardware consists of separate local systems and has multilevel structure. Local system fragment is shown in fig.1. The CAMAC crate blocks or their VECTOR [5] analogs are placed at the low level and are controlled by means of CC. The CAMAC crates are connected in systems by help UNIBUS and controlled by means of PC computer through adapter. Local systems are united in complex and connected with host computer center by ETHERNET.

The technological parameters system ST (realizes control before-starting preparation) and the synchronization system SS (determines moments of switching on installation parts and measuring systems) are control systems in the usual sense. Let's consider of structure (fig.2) and functions of local systems.

Supervisor system SD produces local systems control and provides date acquisition, archiving, processing and display imaging of information from all local systems.

Technological preparation system ST realizes all necessary operations before installation shot. A main operations are measurement of slow changing parameters (distilled water resistance, gases pressure in switches, voltage on condensers etc.) and control of gases pressure and condenser charges processes.

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A Control & Data Acquisition System for Photoelectron Spectroscopy Experiment Station at Hefei National Synchrotron Radiation Laboratory

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Abstract

The paper describes system configuration and software design. The system has the following features: flexible user interface, succinct control levels, strict protection and high intelligence. It can run EDC, CFS, CIS experiment modes very conveniently with SR light source. Its construction and design idea of the system can be applied to other data acquisition systems.

1. Introduction

Photoelectron Spectroscopy Experiment Station at HESYRL works from VUV to soft x-ray wavelength(10ev -- 1000ev), with resolution E/E 10^{-3} and flux 10^{10} phs/s[1]. The present photoelectron spectrometer is imported from VSW (Vacuum Scientific Instruments) Co., U.K. The software package also provided by VSW is mainly designed for regular light source and regular photoelectron spectroscopy analysis techniques, but not suitable for the special requirement of experiment modes with SR source. Up to now, having modified and developed the control system and software, the completely compatible system can not only carry out regular analysis techniques such as Auger Electron Spectroscopy (AES), UV-Photoelectron Spectroscopy (UPS), X-ray Photoelectron Spectroscopy (XPS), but also bring about Synchrotron Radiation Photoemission Spectroscopy (SRPES), Angle Resolved Photoemission Spectroscopy (ARPES), Near Edge X-ray Absorption Fine Structure (NEXAFS) and Photoelectron Diffraction (PED) with controllable SR source. We hope it will promote further research on surface science and material science.

2. Design principle

. Special requirement

The basic principle of photoelectron spectroscopy is to irradiate samples with monochromatic light source, causing photoemission from atoms or molecules, then analyze the electron energy and angular distribution and get the useful information. So a control system for photoelectron spectroscopy experiment is focused on two points: to change exciting source and acquiring methods of electron energy.

Exciting source

The system must control beam line availability, such as wavelength scanning for different users in different experiment techniques, zero order scan, photon intensity detecting and other analog signal measurement.

Four different spherical gratings and entrance/exit slits are installed in the beamline. It is demanded that the rotation of the grating and translation of stepping motor driven entrance and exit slits follow the Rowland circle.

Operating modes

Three operating modes with SR source must be inserted to the system: EDC mode, CFS mode and CIS mode.

.Design principle & implementation scheme

1) It is necessary not only to meet the special requirement above, but also to assume the most succinct man-machine interface. Beamline control is an example. Although there are so many parameters of intelligent motor controller, and the gratings and slits tracing movement is complex, there are just three necessary parameters in the user's interface to execute beamline scanning: grating number, initial and final energy of photon. The new added GPIB interface supports all beamline control.

2) The integrity of the original software manager level structure is to be preserved. All the extended periphery drivers are inserted into Software/Hardware interface layer. The Function layer is expanded and other layers are developed.

3) We assure a complete compatibility with original software both in general and details. In general, it includes the following fields: man-machine interface, experiment queue, file system, image display and protection measure, specific processing such as exciting source selection, experiment technique selection, parameters input and collection, the experiment condition recorded in data file, status display and so on are completely compatible.

3. General description

.General manager level structure

The system structure can be divided into the following layers: User interface layer, Analyzer, Scheduler, Function layer, Software/Hardware interface layer and Hardware layer, as shown in Fig. 1.

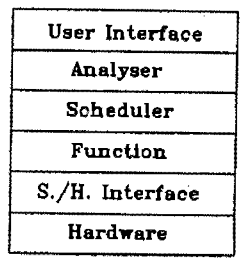

Fig.1 General manager level structure

User Interface layer

This level accepts and analyses preliminary user's input, it checks whether input is legal, displays peripheral equipment status and corresponding processing messages.

Analyzer

It makes a concrete analysis of user's input, then generates some legal results according to user's requirement and hardware environment. At last, the results are sent to the Scheduler.

Scheduler

It issues different function calls in the light of the results sent by Analyzer. If it must be supported by peripheral devices, it will transfer commands or parameters to peripheral devices and get status back through Software/Hardware interface. The calling skill is obtained by use of a special dictionary made of function pointers which just belongs to C language.

Function layer

It executes various concrete functions such as real time image display, reading and writing data files, queuing different experiments, running experiment and acquiring data. This layer and scheduler are the core of the system.

Software/Hardware interface layer

It is the lowest level of the software system. At this level, commands and data are transferred between system and peripheral devices. This layer includes all interface drivers and check of peripheral device status. If a certain device goes wrong or is not ready, a warning message will occur at the user interface.

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Overview of the Next Generation of Fermilab[1] Collider Software

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Abstract

Fermilab[1] is entering an era of operating a more complex collider facility. In addition, new operator workstations are available that have increased capabilities. The task of providing updated software in this new environment precipitated a project called Colliding Beam Software (CBS). It was soon evident that a new approach was needed for developing console software. Hence CBS, although a common acronym, is too narrow a description. A new generation of the application program subroutine library has been created to enhance the existing programming environment with a set of value added tools. Several key Collider applications were written that exploit CBS tools. This paper will discuss the new tools and the underlying change in methodology in application program development for accelerator control at Fermilab.

I. MOTIVATION

Digital VAXstations running X-windows under VMS have replaced the PDP-11s formerly used to control the accelerators. This more powerful platform coupled with the demands of more complicated Collider operation led us to move from an approach of single application-per-need to using fewer applications that draw on a large toolbox of resources. Application programs are now viewed as hooks into a pool of integrated tools. At the same time we must maintain compatibility, while encouraging migration to new tools, for the existing application programs which number in the hundreds. This is done by providing calling sequences which are not too divergent from the existing ones. The new console platform also opened the door for the use of C as an application programming language. Calling sequences are often provided both in call-by-reference for the FORTRAN users and call-by-value for the C users.

[1] Operated by Universities Research Association for the Department of Energy

II. OVERVIEW

All the new tools are layered on top of the older lower-level routines. These subroutines reside in a shareable image. This allows easy growth of a large number of routines without affecting the application programmer. This was necessary so that application development could be done in parallel with the maturation of the CBS environment. The tools handle file access, data acquisition, graphics screen management, window management, inter-program communication and error logging facilities. These utilities also provide their own logging and statistics that are viewable by the user during program execution. Tools that access centralized facilities, such as reading a database, cache information to reduce the load on the centralized processes and the network. Any of the tools with a visual interface follow standards. This provides a consistent user presentation to the operators. This is a more effective way to enforce user-standards, rather than administrative dependent approaches that have failed in the past.

III. DATA ACQUISITION

The first major component in the CBS utilities involves input and output to accelerator hardware as well as reading database information concerning that hardware. This involves reading, setting, controlling, and scaling values as well as handling alarms and miscellaneous device attributes. The previously available interface routines required separate requests for real-time raw data as well as stored data from the database in order to read or set data in engineering units. This required seven low level function calls to retrieve or set a single value in engineering units. In addition to the function calls, additional code was required to perform such necessary tasks as retrying data retrieval until the data is actually received. All of this functionality has been replaced by a single, simple function call. For lists of devices the procedure is only slightly more complex in that there is a function to build the list of devices and a second function to read or set the list.

The database information for scaling and necessary interface to front end software is cached locally. This reduces redundant database access and network traffic. The data acquistion routines perform the access and caching such that it is

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IDEAS ON A GENERIC CONTROL SYSTEMS BASED ON THE EXPERIENCE ON THE 4 LEP EXPERIMENTS CONTROL SYSTEM

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Most of the large slow control systems in the LEP collider experiments are distributed heterogeneous and multi-standard. But in spite of the appearances, they have a lot in common. From our direct experience on the L-3 slow control system and from the informations we obtained on the 3 other LEP experiments control systems we have come to the conclusion that it should be possible to build a Generic Control Package from which any control system could be derived. This software package is entirely based on relational databases and is intended to provide all the necessary tools to build a modular, coherent, easy to update and to maintain control system. Among other things this package should include user friendly interfaces, expert systems, and powerful graphic monitoring and control tools. This paper will present our general ideas about the realization of such a package.

1. Introduction

The need for large and dedicated Slow Control Systems for the High Energy Physics Experiments at CERN only became clear with the construction of the LEP collider. The large number of parameters involved in the controls as well as their wide distribution over the sites forced physicists to reconsider the entire organization of such systems. In this paper, the 4 LEP experiments control systems will be presented in some details followed by a summary of their main characteristics. Out of this study some general ideas which could be used for the elaboration of generic tools for future Slow Control systems will be presented.

2. The 4 LEP experiments Slow Controls

The 4 experiments are composed of many sub-detectors and several thousand operational parameters which have to be set and monitored in order to insure that the experiments are in a correct state for data-taking. These include quantities such as high and low voltages, temperatures, pressures and gas mixtures. The role of these Slow Control Systems is to monitor the experimental conditions locally and generate alarms in the main control room when faults are detected. Operators alerted by the alarm signals correct for the fault either manually or remotely via a computer. The systems are also used for the routine setup of operating conditions for example high voltages, general monitoring and logging of operating conditions.
Since the quantities to be monitored vary only on a time scale of seconds the slow control systems need not to have very fast responses. However, they must be very reliable and able to handle a large number of very different parameters.

2.1 The ALEPH Slow Control [1]

The ALEPH system is implemented in a number of distinct parts which are listed below:

1) Independent control and monitoring programs for each sub-detector run on VAX™ computers configured in a VAX™ cluster. These main displays of the currently monitored equipments allow operators to control the detectors and log the information to storage media.

2) All the sub-detectors slow control programs communicate with their equipment via a single server program running on a dedicated microVAX™ 3100 workstation in the cluster (fig. 1). The slow control server is the only program which communicates directly with the microprocessor system outlined below, which monitors and control the equipment. An interactive graphical status display showing the layout and status of the system is also implemented on this station.

3) Low-level monitoring and control functions are performed by programs running in a distributed system of microprocessors attached to the sub-detector hardware. They are capable of understanding, executing and replying to simple commands sent to them from the VAX server program.

4) Networks are used for communication between the slow control server and the microprocessors. The processors are connected to a number of UTI-NET

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The LEP Alarm System

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Abstract

Unlike alarm systems for previous accelerators, the LEP alarm system caters not only for the operation of the accelerator but also for technical services and provides the direct channel for personnel safety. It was commissioned during 1989 and has seen a continued development up to the present day. The system, comprising over 50 computers including 5 different platforms and 4 different operating systems, is described. The hierarchical structure of the software is outlined from the interface to the equipment groups, through the front end computers to the central server, and finally to the operator consoles. Reasons are given for choosing a conventional, as opposed to a 'knowledge based' approach. Finally, references are made to a prototype real time expert system for surveying the power converters of LEP, which was conducted during 1990 as part of the alarm development program.

I. Introduction

The Large Electron Positron Collider (LEP) was constructed during the years 1983 to 1989 and is situated in a 27km tunnel of diameter 3.8 metres at a depth varying between 50 and 175 metres. It contains 4 experimental halls situated symmetrically around the ring of size approximately 80 metres long and 23 metres in diameter. From the very outset it was decided to survey the whole complex both for personnel safety and equipment status by 1 alarm system due to the sheer size of LEP and cost of system installation. This task was given to an 'Alarm Team'. A major milestone for the project was the use of a complete prototype for the 'LEP Injection Tests' in July 1988. By 1989, in time for 'LEP Switch On' the system had become stable and operational, but with an incomplete coverage of the complex and only a rudimentary display for information presentation. A continued development concentrated on improving the Man Machine Interface (MMI), and extending the scrutiny of the surveillance system while investigating alternative techniques to improve the overall system.

II. The Alarm System Project

A. Definition

The alarm system can be thought of as a window through which operators can view the status of any part of the process. Here the process concerns the whole accelerator, equipment associated with personnel safety and the control system itself. By definition, if there is nothing wrong with the process, it is assumed that the overall state is good, and therefore no alarm information is presented. On the other hand, whenever a piece of equipment does not work, or an abnormal state is detected, a description of this situation should be passed to the system. This description is termed a Fault State (FS) and covers both warning and alarm situations. The alarm system concerns the acceptance, treatment and display of these FS's.

B. Organisation

The project began in earnest in 1987 and has been continually staffed by 1 permanent and, on average, 3 temporary personnel. During the 5 years of system design, implementation and development, 16 temporary personnel, each working on average 1 year have contributed 18 man years to the project. These people were all trained in computer science, apart from 1 who was an experimental physicist. The permanent member managed and coordinated the project which was divided into 4 areas: display and presentation of information to operators, a Central Alarm Server (CAS), an interface to the users responsible for the equipment, and a database.

As part of the organisation of the LEP project, it was stated that each equipment group should be responsible for its own equipment surveillance. It was envisaged that the main part of this task would be done in the equipment groups' local control environment called Equipment Control Assemblies (ECA's). Unfortunately, in reality little surveillance of equipment was implemented at that level. This required that the interface between the alarm system and the equipment groups, in many cases passed beyond the ECA right down to the level of the equipment. For this reason it was even more important to define exactly where each line of responsibility was drawn. In practice this was always done at the level of a database definition, either at the FS description level or a combination of a command/response definition to acquire an equipment state and its corresponding FS definition.

C. Influencing Factors

The main influencing factors were the following:
1. At the very beginning of the project various groups at CERN were evaluating the possible uses of Expert Systems (ES). At one time an 'Expert System Interest Group' was set up which encouraged a free exchange of ideas and helped keep abreast of developments. Although nothing of practical value resulted for LEP, one area, a project in the Controls Group of

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The Software for the CERN LEP Beam Orbit Measurement System

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The Beam Orbit Measurement (BOM) system of LEP consists of 504 pickups, distributed all around the accelerator, that are capable of measuring the positions of the two beams. Their activity has to be synchronized, and the data produced by them have to be collected together, for example to form a "closed orbit measurement" or a "trajectory measurement". On the user side, several clients can access simultaneously the results from this instrument. An automatic acquisition mode, and an "on request" one, can run in parallel. This results in a very flexible and powerful system.
The functionality of the BOM system is fully described, as well as the structure of the software processes which constitute the system, and their interconnections. Problems solved during the implementation are emphasized.

Introduction

The Beam Orbit Measurement (BOM) [1, 2] system is one of the most vital instruments of LEP, and it is potentially very powerful. 504 pickups, connected to 40 VME crates, are distributed all around the LEP ring . Each pickup can acquire a signal induced by the passage of each single bunch of particles and record it in a VME compatible memory card. Each crate is equipped with two such cards, ("Main" and "Secondary"), which can store signals coming from up to 1800 (450 for the secondary) turns. The signals are processed locally by microprocessors in the VME crates (called DSC, from Device Stub Controller), and then finally collected in a single computer to produce the final result (typically, the LEP orbit).
Due to various reasons (limited CPU power in the VME crates, incompleteness of the software, unfriendliness of the RMS68K programming environment on the VME crates and the reorganisation of the CERN accelerator divisions), the potential of the system had never been fully exploited. For this reason, in July 1990 it was decided to upgrade the computer part of the BOM system, both from the hardware and from the software side. Major points of the upgrading were :

1. Replacing the DSC 68010 CPUs with 68030 CPUs equipped with floating point coprocessor.
2. Replacing the RMS68K microprocessor operating system of the DSCs with OS9. The new DSC systems would be diskless and would load system and application programs from a common file server. This would make the overall system cheaper, more reliable and easier to maintain.
3. Using a dedicated Apollo workstation (the BOM Server) to collect the data coming from the DSCs and to deliver the results to the users of the BOM system.
4. Implementing direct network connections, based on the TCP/IP protocol, between the DSCs and the Apollo workstation where the data have to be put together.
5. Finally, a complete redesign and rewriting of the software to be run both on the DSCs and on the Bom Server . This will be the main subject of this article.

Constraints (and flexibility) : How the system works.

When upgrading an existing system, some degrees of freedom are frozen. A preliminary step to perform is to examine the things that cannot be changed; the new system will have to live with them.
In the LEP BOM system, the data acquisition in the 40 DSCs is triggered and synchronized by the Beam Synchronous Timing (BST) system [3, 4, 5]. This system interprets "tasks" written in a pseudo-assembler language. At each LEP turn the BST distributes an identical message to all 40 DSCs. This message contains a part which can be read by programs running in the DSC, and a part directly received by the hardware installed in the VME crate. As mentioned in the Introduction, in each crate there are two "Acquisition" memory cards. By software it is possible to independently set the access to these memories in one of two modes ,"intern" or "extern". In the "intern" mode the memory is made accessible to the processes running on the DSC CPU, whereas in "extern" mode the memory can receive data from the BOM data acquisition electronics (FADCs). The FADCs produce data every time a bunch of particles crosses the pickup. If the access to a memory is set as "extern", and a certain bit of the BST message received at a given LEP turn is set to 1, then the data produced by the FADCs during that turn will be written into the memory, together with the arrival times of the various bunches.
The pickups close to the intersection points are equipped with Wide Band electronics, while the rest of the pickups are equipped with Narrow Band electronics. The Narrow Band pickups can measure, during the same turn, the signal generated by each bunch of each beam circulating in LEP. The Wide Band pickups only measure the signal generated by bunches of a preselected beam.
The fact that the system has two acquisition memories provides a certain flexibility. It is able to perform two different operations at the same time, one in the Main memory, the other in the Secondary memory. The two memories can be considered as belonging to two different instruments.
There are, however, a few constraints which have to be dealt with :

1. While the Narrow Band systems can acquire both beams at the same time, the Wide Band systems cannot. Their settings have to be changed if one needs to change the type

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A VMEbus General-Purpose Data Acquisition System

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November 8, 1991

***Abstract* — We present a general-purpose, VMEbus based, multiprocessor data acquisition and monitoring system. Events, handled by a master CPU, are kept at the disposal of data storage and monitoring processes which can run on distinct processors. They access either the complete set of data or a fraction of them, minimizing the acquisition dead-time. The system is built with the VxWorks 5.0 real time kernel to which we have added device drivers for data acquisition and monitoring.**

The acquisition is controlled and the data are displayed on a workstation. The user interface is written in C++ and re-uses the classes of the Interviews and the NIH libraries. The communication between the control workstation and the VMEbus processors is made through SUN RPCs on an Ethernet link.

The system will be used for, CAMAC based, data acquisition for nuclear physics experiments as well as for the VXI data taking with the 4π configuration (100 neutron detectors) of the Brussels-Caen-Louvain-Strasbourg DEMON collaboration.

I. INTRODUCTION

Experiments differ in the way they produce data: they use different standards of hardware to digitize data (VME, VXI, CAMAC, ...); they generate data varying in byte length and counting rate. However, the last stages of data acquisition systems have many things in common: the data are analyzed on-line to control the experiment and are written on storage devices for further off-line analysis.

We have defined a common framework for a general-purpose data acquisition system. It meets the following requirements:

- the data source is open: the system can be enabled to acquire data from various instrumentation buses;
- the data sink is open: data can be analyzed on-line by concurrent processes and can be stored on different types of mass storage devices;
- the system is scalable: it can be used for low count rate nuclear physics experiments (20 byte events at 200 Hz) as well as in larger experiments such as the 100 neutron detectors of the DEMON collaboration [1] (300 byte events at 5 kHZ);
- the user sits at the highest level of the data acquisition system with the modern conveniences of workstations.

II. SYSTEM ARCHITECTURE

A. Distributed Hardware

The system is designed following a distributed architecture (Figure 1). The real-time data acquisition is performed by a VMEbus system. It allows to connect a wide variety of interfaces to external hardware as well as to run data acquisition processes by various processor boards. The user acquisition control and data handling is delegated to a standard workstation connected to the VMEbus system by an Ethernet link.

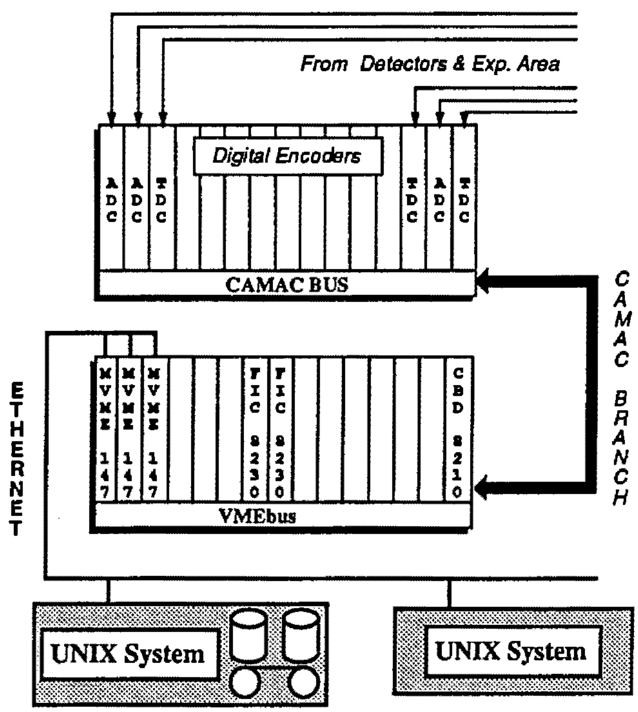

Figure 1: A Simple Distributed Architecture

In such an architecture, both parts are loosely coupled and may be evolved on their own. The user workstation or the VMEbus system may be replaced or upgraded without redesigning the entire system.

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Interfacing Industrial Process Control systems to LEP/LHC

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Abstract

Modern industrial process control systems have developed to meet the needs of industry to increase the production while decreasing the costs. Although particle accelerators designers have pioneered in control systems during the seventies, it has now become possible to them to profit of industrial solutions in substitution of, or in complement with the more traditional home made ones. Adapting and integrating such industrial systems to the accelerator control area will certainly benefit to the field in terms of finance, human resources and technical facilities offered off-the-shelf by the widely experienced industrial controls community; however this cannot be done without slightly affecting the overall accelerator control architecture. The paper briefly describes the industrial controls arena and takes example on an industrial process control system recently installed at CERN to discuss in detail the related choices and issues.

I. INTRODUCTION

Computers have gained a major importance in the overall design, construction, operation, maintenance and exploitation of today's accelerators and it is not exaggerated to say that, without them, physics research would not have become what it is, and conversely that the development of computers was highly due to the needs of basic research.

Pioneering in a statistic based research domain like particle physics leads the engineers and physicists to work at the limit of what is possible in fields like electronics, mechanics, computing, materials,etc.. They have to look permanently for and to try to make profit of new promising technologies, as soon as these emerge from laboratories. They then get used to live ahead of industry in a lot of scientific fields. They finally accept as a fact of life to develop everything they need, because they do it better, tailored to their needs, with higher performance than what they can readily find.

This is the case at CERN where people have felt in the early days the potential embedded in the computers to help them solving controls problems. Many of the basic components which make up a particle factory are now well known and currently manufactured by industry. The particle accelerators are quite comparable to other industrial machines. The running of a particle factory leans mostly on domains for which industry has developed several control systems solutions. One may profit today of this opportunity, in our new era of restricted human and financial resources.

II. THE COMPONENTS OF AN ACCELERATOR

A. *Inventory of components*

Components may be classified into two categories depending whether or not they actively participate in the production of particles: the first category will be referenced as *active* in this paper and the second as *passive* (see figure 1). Magnets, RF cavities, electrostatic separators, power converters, beam instrumentation are *active* components. All play an active role in keeping an accelerator state as well as in performing the transitions from one state to another. Electricity, vacuum, cooling & ventilation, cryogenics, personnel protection, site access are *passive* components.

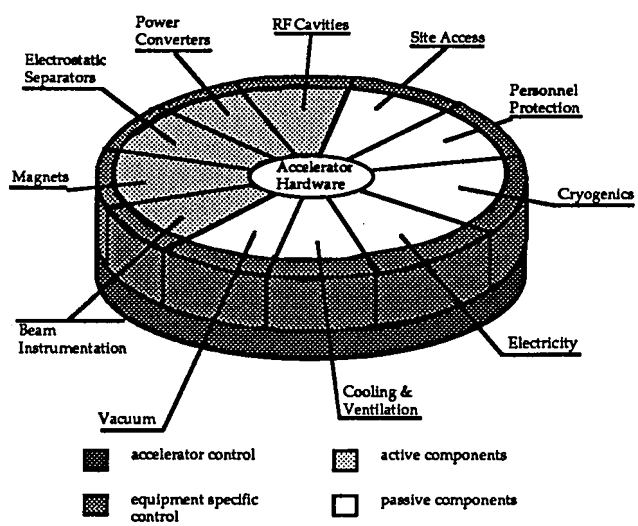

Figure 1. Accelerator components

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SPS/LEP Beam Transfer Equipment Control Using Industrial Automation Components

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Abstract

Several control systems for SPS and LEP beam transfer equipment have to be commissioned in the near future. Tools for fast software development, easy maintenance and modifications, compliance with industrial standards, and independence of specific suppliers are considered to be essential. A large fraction of the systems can be realized using off-the-shelf industrial automation components like industrial I/O systems, programmable logic controllers, or diskless PCs. Specific electronics built up in G-64 can be integrated. Diskless systems running UNIX and X Windows are foreseen as process controllers and local access media.

I. INTRODUCTION

Within the SPS and LEP Beam Transfer sector at CERN, there are currently several control systems being prepared for the application in both accelerators. Among those are, in different phases of progress, the control for the LEP beam dump and for the LEP Pretzel beam separators.

Whereas the size and the complexity between our different systems varies considerably - from some 10 I/O channels to nearly 1000 - all systems can commonly be characterized as 'slow controls', i.e. the required response times as seen from the main control room are only in the order of seconds for most actions. Specific fast responses, e.g. for beam dumping, are supported by special hardware. The size of data exchanged between the main control room and the equipment is relatively small. However, the significance of the equipment for the machine operation requires a continuous monitoring of its performance and efficient diagnostic tools for debugging in case of failure.

To facilitate the running of an increasing number of systems with different functionality and different composition with the available manpower we are looking for rationalization opportunities. Inspired by investigations in the field of industrial process automation several areas have been identified. In this article we try to demonstrate how we plan to apply our findings in the coming generation of control systems.

In the following we shall first discuss the criteria which we consider essential for the selection of the appropriate components. Afterwards, the characteristics of the preferred field bus will be given. Then, the full concept will be presented complemented by a brief status report.

II. SELECTION CRITERIA

A. Hardware Interface

While the prices for equipment electronics in general are decreasing, any cabling, either inside crates and racks or between racks and equipment, is becoming a dominant cost factor, besides being error prone. Therefore all data should be picked up by remote I/O systems where they arise, whenever possible and if not totally inconvenient. All I/O systems belonging to the same logical system should be hooked to a field bus connected to a process controller.

A second factor is a clean and simple rack cabling scheme including appropriate connection systems permitting a fast and cost saving installation and modifications and an easy maintenance of the electronics.

Other important criteria concern the economic use of rack space and the cost, reliability, and the technological lifetime of the selected I/O systems.

B. Local and Remote Access Facilities

Since the equipment to be controlled is, for technical reasons, sometimes far away from the process control computer or even the I/O system, one has to provide means to influence or monitor the process locally (i.e. without the need to communicate to somebody in front of the computer), e.g. for debugging or calibrating an equipment. This can be done using local hardware, e.g. panels with DVMs, switches, and potentiometers, hand-held terminals in the case of programmable logic controllers, or portable PCs. It is essential to enable the person in charge of maintenance to get access to all important parameters of the system in a user-friendly form and to permit to develop or to modify test procedures rapidly.

Adequate facilities have to be added on the process controller level and on other systems from where people have to access the equipment, which should be as complete as possible, preferentially without much adaption work for different platforms.

C. Software

The equipment software can be a particularly problematic area in that here the user requests have to be translated into specific instructions by comparatively few specialists. The

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EPICS Architecture*

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Abstract

The Experimental Physics and Industrial Control System (EPICS) provides control and data acquisition for the experimental physics community. Because the capabilities required by the experimental physics community for control were not available through industry, we began the design and implementation of EPICS. It is a distributed process control system built on a software communication bus. The functional subsystems, which provide data acquisition, supervisory control, closed loop control, archiving, and alarm management, greatly reduce the need for programming. Sequential control is provided through a sequential control language, allowing the implementer to express state diagrams easily. Data analysis of the archived data is provided through an interactive tool. The timing system provides distributed synchronization for control and time stamped data for data correlation across nodes in the network. The system is scalable from a single test station with a low channel count to a large distributed network with thousands of channels. The functions provided to the physics applications have proven helpful to the experiments while greatly reducing the time to deliver controls.

I. INTRODUCTION

EPICS is currently being co-developed by the Accelerator Technology controls group at Los Alamos National Laboratory and the Advanced Photon Source controls group at Argonne National Laboratory. Its architecture provides a wide range of functionality, rapid application development and modification, and extensibility at all levels to meet the demands of experimental physics. The hardware and software for each functional subsystem was seleceted to meet these requirements. The subsystems are: the Distributed Database, the Display Manager, the Alarm Manager, the Archiver, the Sequencer, and Channel Access [figure 1]. Technology changes, to be incorporated, will further extend the performance of the EPICS subsystems. Programs at various installations have applied EPICS successfully with no modifications to the software, demonstrating adequate performance, functionality and extensibility.

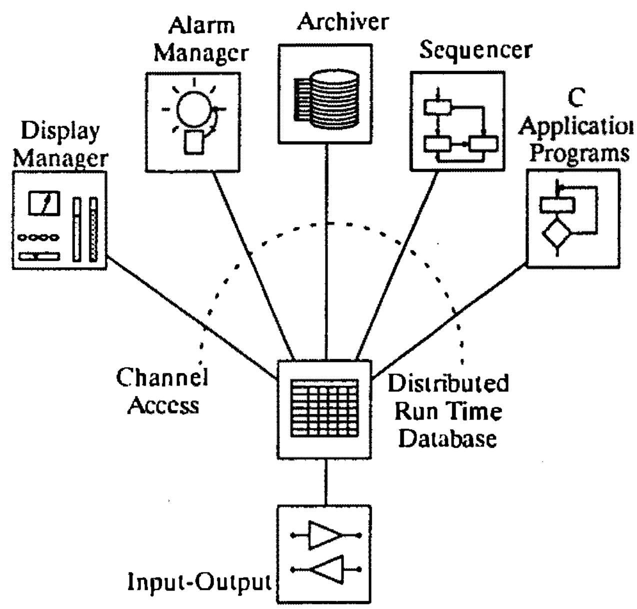

Figure 1. Functional subsystem layout of EPICS.

II. THE DISTRIBUTED DATABASE

A distributed database is used to provide local control. A portion of the distributed database is loaded in each I/O Controller (IOC). The database provides data acquisition, data conversion, alarm detection, interlocks, and closed loop control[1][2].

The IOCs, in which the database segments are loaded and executed, consist of a VME or VXI backplane, a 68020 CPU running the vxWorks real-time kernel, an ethernet connection, and an optional complement of I/O [Figure 2]. The I/O buses supported are: VME, VXI, Allen-Bradley Industrial I/O, GPIB, BITBUS, and CAMAC. The benchmarks for the database scan tasks show the ability to close 4,000 analog loops per second leaving about 40% of a 68020 available for the sequencer and channel access

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A Front-End System for Industrial Type Controls at the SSC

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Abstract

The SSC control system is tasked with coordinating the operation of many different accelerator subsystems, a number of which use industrial type process controls. The design of a high-performance control system front end is presented which serves both as a data concentrator and a distributed process controller. In addition it provides strong support for a centralized control system architecture, allows for regional control systems, and simplifies the construction of inter-subsystem controls. An implementation of this design will be discussed which uses STD-Bus for accelerator hardware interfacing, a time domain multiplexing (TDM) communications transport system, and a modified reflective memory interface to the rest of the control system.

I. INTRODUCTION

The design of a control system for the SSC faces significant challenges arising from its immense physical size, plethora of control points, and wide range of time scales for controls. At the slow end of the time scale there are accelerator subsystems like cryogenics, vacuum, low-conductivity water, and industrial cooling water which use industrial process controls. For a proper perspective consider the vacuum controls. A recent estimate indicates that there will be 50,000 to 60,000 points divided among 200 niches around the ring. This number, which does not include vacuum controls for the injector accelerators or beam lines, is roughly comparable to the total FNAL control system. The cryogenic system is 2-3 times larger than the vacuum system. The controls for these SSC accelerator subsystems totaling more than 250,000 points dwarf most large industrial and high-energy physics control systems. The present paper describes a possible front-end system for process controls at the SSC. An earlier discussion of this system can be found in Ref. [1].

II. DESIGN REQUIREMENTS

The controls for these subsystems at the SSC must support process controls and smoothly integrate into the rest of the SSC control system. A general list of requirements appropriate for this discussion are as follows:

1. Provide industrial process controls.
2. Minimize hardware in hostile or radiation areas.
3. Use open, widely available industrial standards.
4. Prefer commercial products to custom hardware.
5. Set no limits on the number of control points.
6. Execute control functions at different system levels.
7. Support a centralized control system architecture in which the entire complex is operated from a single location.
8. Provide regional level controls to support commissioning and maintenance of large accelerator components.
9. Eliminate accelerator hardware data hiding in the control system architecture.
10. Facilitate near real time inter subsystem information sharing and implementing geographically distributed or inter subsystem control loops.
11. Contain costs.
12. Maximize reliability.
13. Follow the overall SSC control system architecture.

While meeting many of the process control requirements for individual subsystems, commercial process control systems have problems supporting either the large number of control points or extended geographical area or desired level of integration.

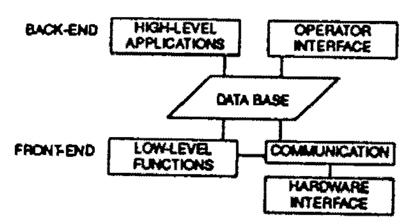

Figure 1. Front-end system components in relationship to the rest of the control system.

III. FRONT-END SYSTEM DESIGN

In Fig. 1 the basic components of the front-end system are show in relationship to the rest of the system. The front end consists of the interface hardware, communications, and processors to execute low-level control functions. It supports data I/O and functions such as loops, alarm monitoring, and interlocks. The back end is commercial and SSC developed software providing operator interface and high-level control applications such as complex sequencing, expert systems for alarm analysis, data logging, and process simulation. Effectively the high-speed reflex-like control activities are

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The Influence of Industrial Applications on a Control System Toolbox

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Abstract

Vsystem is as an open, advanced software application toolbox for rapidly creating fast, efficient and cost–effective control and data–acquisition systems. Vsystem's modular architecture is designed for single computers, networked computers and workstations running under VAX/VMS or VAX/ELN. At the heart of Vsystem lies Vaccess, a user extendible real–time database and library of access routines. The application database provides the link to the hardware of the application and can be organized as one database or separate databases installed in different computers on the network. Vsystem has found application in charged–particle accelerator control, tokamak control, and industrial research, as well as its more recent industrial applications. This paper describes the broad features of Vsystem and the influence that recent industrial applications have had on the software.

I. Introduction

Developing control systems for physics research from basic components requires considerable effort and the acceptance of risk. Now, software products that can form the basis of an experimental physics control system are entering the product market. This paper describes one such product. Software products exist that were developed originally for factory automation but experience has shown that these products do not network well and are difficult to apply in a research environment, often costing more in total than a home–written system! Vista Control Systems has gone the other way—finding industrial markets for control system software originally developed for physics research. These new industrial applications have added to the flexibility of the Vsystem software in a way that benefits all users without threatening the flexibility and openness of Vsystem.

Vsystem consists of several modules: Vaccess, Vdraw, Vscript, Valarm, Vlogger, and a number of utilities.

II. Vsystem's Real–Time, Networked Database

The architecture of Vsystem requires that all components of the application, be they supplied with Vsystem or user–written, communicate only through the Vaccess database. A system's Vaccess database is defined by ASCII files and installed as global sections. The overall application database is usually made up from individual components distributed among the computers of the system. Collectively, the databases are a data model of the application, modelling both the actual connections and derived data.

The Vaccess database has many real–time features including change notification, alarm and warning checking, dynamic linking of hardware access and data conversion subroutines, and automatic I/O. There are many fields in each channel, or record, of the database that allow the modelling to be complete. Each channel is known by a name up to 40 characters long which is defined by the project. Database channels support most data types as either single valued or array channels. Table 1 lists the channel fields of Vaccess V2.2.

Channel Fields	Channel Name Current Value Current Value Significant Change Equipment Limits Clipping Enable Channel Data Type Read Only Enable, Constant Channel Channel Text Label Interest Count
Conversion Fields	Conversion Subroutine Name Conversion Enable Conversion Parameters (10) Built–in Linear Conversion Parameters (2)
Alarm Fields	Alarm and Warning Checking Enable Alarm and Warning Limits Alarm Label Alarm Type (Integer Channel)
Hardware Fields	Automatic I/O Enable I/O Type Hardware Type Hardware I/O Subroutine Name Hardware I/O Function Hardware Parameters (10) Survey Rates Automatic Survey Enable Input or Output
Display Fields	Display Limits Text Display Format Data Units

Table 1. Vsystem Database Fields

A. *Database Access Routines*

A library of access routines allows full access to the run–time database. Routines are included to search the database in various ways and to request and cancel change notification by wake–up

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ARCNET as a Field Bus in the Fermilab Linac Control System

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Abstract

Data acquisition hardware in accelerator control systems is connected by a field bus to networked computers that supply data to consoles. Industry attempts to standardize on a low level field bus have not succeeded in providing a single well-supported bus. This paper describes a data acquisition chassis that connects to VMEbus computers using ARCNET, a full featured token-passing local area network, as the field bus. The performance of this technique as implemented in the control system for the Fermilab Linac is given.

I. Introduction

A field bus is the connection between local computers and the interface hardware that controls accelerator equipment. Various field buses have been used by control system designers, but no single bus has emerged as a widely used standard. Example field buses are MIL-1553, Bitbus, and CAMAC.

This paper describes the use of ARCNET as a field bus in the Fermilab Linac Upgrade project. The output energy of the Linac injector is being increased from 200 MeV to 400 MeV by replacing the last four of the nine 200 MHz Alvarez tanks with 800 MHz side-coupled structures. This upgrade doubles the beam energy in the same accelerator enclosure. The control system being designed as part of the upgrade, will be installed for the preaccelerators and the remaining five 200 MHz tanks as well as the new 800 MHz sections.

II. ARCNET as a Field Bus

If the interface hardware that connects to accelerator equipment is dumb, then the field bus must be register-based. Such buses have limited addressing capacity and the amount of data transferred per transmission is small. Nodes on register-based field buses usually operate as slaves that must be polled by a master computer to collect their data.

If the interface hardware contains a processor, then a local area network can be supported. Benefits of using a local area network include longer messages, higher data transmission rates, longer distance connections, and peer protocol communications that allow a remote node to source a message without being polled. A single message may contain all the analog and digital data collected by a node.

Characteristics of ARCNET include:

- 2.5 MHz serial bit rate
- 508 byte maximum message length
- Bus, multiple star and daisy-chain topology
- Coax, twisted pair and fiber optic transmission media
- Maximum distance without repeaters >600 m. (coax)
- Transformer isolated cable drivers
- Deterministic token passing access protocol
- Built-in acknowledgment of successful message reception
- Network configuration and timeouts implemented in controller chips

Compared with the characteristics of ARCNET, typical field buses are much lower in performance: MIL-1553 operates at one MHz, has a maximum message length of 32 words and can address 32 locations per node; Bitbus is not transformer coupled and is limited to 375 kHz for reasonable distances; normal CAMAC commands access only three bytes. All of these buses use master-slave communication protocols.

III. Architecture of the Linac System

The overall design of the Linac control system follows the standard architecture of local VMEbus 68020 computers networked to each other and to console workstations by an IEEE-802.5 Token Ring. A separate ring is used for the Linac VMEbus stations and the connection to the central control system is made by a commercial multiport Token Ring-to-Token Ring bridge. This organization isolates the traffic on the Linac ring from all other network traffic.

A. System Hardware

Individual VMEbus computers, called Local Stations, contain a core set of five cards; a 68020 processor, a 1MByte non-volatile RAM card, the Token Ring adapter, a crate utility card and an ARCNET adapter. All but the crate utility card are commercially available. Each VMEbus station acts as a stand-alone control system complete with its own database and software resident in the non-volatile RAM. Following a power outage, these systems reset, reconnect to the network, and send the last known settings to the hardware. Because they have non-volatile RAM, Local Stations do not require routine downloading. Local Stations run synchronously with the 15

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Multi-processor Network Implementations in Multibus II and VME

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Abstract

ACNET (Fermilab Accelerator Controls Network), a proprietary network protocol, is implemented in a multi-processor configuration for both Multibus II and VME. The implementations are contrasted by the bus protocol and software design goals.

The Multibus II implementation provides for multiple processors running a duplicate set of tasks on each processor. For a network connected task, messages are distributed by a network round-robin scheduler. Further, messages can be stopped, continued, or re-routed for each task by user-callable commands.

The VME implementation provides for multiple processors running one task across all processors. The process can either be fixed to a particular processor or dynamically allocated to an available processor depending on the scheduling algorithm of the multi-processing operating system.

I. INTRODUCTION

The motivation for a multi-processor platform in Fermilab's Accelerator Controls Group was to support our extensive commitment to CAMAC. The goal was to provide a replacement for PDP11 front-ends improve the effective utilization of the CAMAC serial link. Since CAMAC can have only one master, the link hardware allows ownership to be passed between cooperating processors. One of the requirements for this configuration was to implement ACNET communications for several duplicate processors running identical set of tasks. Thus, processors can be transparently added to the configuration with a corresponding increase in performance. This requirement provided the impetus for a multi-processor network connection to the existing network. The VME implementation provides support of multi-processor networks by using MTOS-UX MP (multi-processor version) operating system for transparent distribution of tasks among a set of processors.

† *Operated by Universities Research Association for the Department of Energy.*

II. ACNET OVERVIEW

ACNET (Accelerator Controls Network) is Fermilab's proprietary network protocol implemented in 1980. It consists of both a software protocol and a calling sequence specification.

The software protocol consists of a 9 word header (figure 1) preceding each message and provides a specification for the routing of messages between tasks. The protocol maintains a connection between cooperating tasks through a status reply and/or cancel messages. These notifications enable tasks and the network to maintain connectivity and cleanup network resources with minimal overhead.

The calling sequence provides a consistent user interface across heterogeneous machines and enables a request/reply paradigm for communication. Both asynchronous communications (traps, signals, or event flags) and synchronous communications (polling, wait, or wait with time-out) are supported by the calling sequence.

This calling sequence has enabled Fermilab to isolate effects to users due to changes in either the software or hardware protocol. While the implementation imposes inherent software costs, there is an advantage in providing a consistent layered approach for other software protocols.

The proprietary protocol does not restrict the use of standard protocols. For instance, by tunneling or encapsulating software protocols, ACNET has been implemented through a DECNET protocol and will be implemented with TCP/IP in the near future. The primary reason for not implementing a standard protocol stack has been the lack of support by vendors for the current set of heterogeneous processors and operating systems at Fermilab.

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A DISTRIBUTED DESIGN FOR MONITORING, LOGGING, AND REPLAYING DEVICE READINGS AT LAMPF *

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Abstract

As control of the Los Alamos Meson Physics linear accelerator and Proton Storage Ring moves to a more distributed system, it has been necessary to redesign the software which monitors, logs, and replays device readings throughout the facility. The new design allows devices to be monitored and their readings logged locally on a network of computers. Control of the monitoring and logging process is available throughout the network from user interfaces which communicate via remote procedure calls with server processes running on each node which monitors and records device readings. Similarly, the logged data can be replayed from anywhere on the network.

Two major requirements influencing the final design were the need to reduce the load on the CPU of the control machines, and the need for much faster replay of the logged device readings.

I. INTRODUCTION

The Los Alamos Meson Physics Facility (LAMPF) linear accelerator, the injection lines, the experimental areas, and the Proton Storage Ring (PSR) contain over 16,000 beam line devices (approximately 11,000 in the LAMPF Control System (LCS) and 5,000 in the PSR control system) which can be accessed through the LCS Data System [1]. These devices include both monitoring and control devices which occur throughout the facility. Many of the devices are accessed through remote microVAXes which are connected by Ethernet to form a DECnet LAN with the main control computer, a VAX 8650. This system is becoming more distributed as remote computers are added to allow access to related groups of devices, and some of the CPU load is being off-loaded from the main computer to remote machines. The increased distribution of the system has made it necessary to redesign some of the software to take advantage of the changes. One such system is the software that monitors, logs and replays readings from devices located throughout the facility. Before the redesign of the software was started, a complete re-evaluation of the requirements of the software was carried out so that other improvements could be included in the new design.

* Work supported by the U.S. Department of Energy

II. FUNCTIONALITY OF THE SOFTWARE

2.1 The Sampling Software

A large number of beam line devices can be sampled periodically for the purpose of monitoring the device to determine if its reading is within a given range, logging the device reading to a history file, or both. The frequency at which each device is sampled can vary from once a second to once every eight hours. If a device which is being monitored is found to have a reading outside its given range (ie. it is out of tolerance) the accelerator operators are notified via the operator console and an error log. An alarm action may also be initiated. If the device reading is being logged to a history file for replay the reading is recorded together with a device identifier, a compressed timestamp, and the status of the read.

2.2 The Replay Software

The device readings can be replayed for a selected time period and displayed as graphs. Readings from several devices can also be combined in an arithmetic expression and plotted.

III. THE SOFTWARE DESIGN

The sampling software is divided into two parts; the program which collects the data and monitors and logs it, and the operator interface software which allows the operators to interact with the sampling program. Interactions include stopping and starting the sampling of individual devices or lists of related devices, changing the parameters associated with a device, such as the frequency of sampling, and requesting an immediate monitoring of a set of devices.

3.1 Problems with the Original Design

Originally the sampling software was designed to run on the main control computer and to monitor and log data from throughout the facility in a large, central, history file. Replay of device readings was carried out on the same computer.

As more nodes were added to the network the demand for distributed replay grew. Also the number and frequency of device sampling increased, so that the load on the control computer became more noticeable causing a degradation in the speed of execution of other applications, and affecting the ability of the facility operators to respond quickly to requests from experimenters or to emergencies. Due to the increasing size of the history file, replay of the device readings was also

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Synchronous Message-Based Communication For Distributed Heterogeneous Systems

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Abstract

The use of a synchronous, message-based real-time operating system (Unison) as the basis of transparent inter-process and inter-processor communication over VME-bus is described. The implementation of a synchronous, message-based protocol for network communication between heterogeneous systems is discussed. In particular, the design and implementation of a message-based session layer over a virtual circuit transport layer protocol using UDP/IP is described. Inter-process communication is achieved via a message-based semantic which is portable by virtue of its ease of implementation in other operating system environments. Protocol performance for network communication among heterogeneous architectures is presented, including VMS, Unix, Mach and Unison.

1 Introduction

The use of domain-driven object modeling techniques in the specification of the KAON Factory Control System[1] was in contrast to the more traditional emphasis on implementation and technology details and the consequent imposition of the technology on the requirements. When these object-oriented methods were used to model the KAON Factory Control System and to allocate the requirements specification to processor units[2], a *logical* architecture was derived which consisted of a network of distributed processors connected by two specialized communications buses: the *control* bus, a fast communication link responsible for the deterministic transport of control information and the *data* bus, a wide bandwidth link responsible for non-deterministic, data-intensive communication.

Since no generic processor platform can economically perform all of the functions required, the distributed network of computing platforms utilized by the KAON Factory Central Control System (KF CCS) will be non-homogeneous and will undoubtedly consist of both real-time and non real-time platforms. It is therefore important that a consistent software architecture be employed to implement communication among these platforms.

2 Message Based Architecture

The message-based semantic is a candidate for implementing the transparent, high performance inter-process and inter-processor communication required for the KF CCS. *Message passing* can elegantly encapsulate both task synchronization and data transfer into a small set of simple primitives having well-defined semantics[3]. Since a message header can identify a particular *method* to be used by a task *instance*, the use of the message-based semantic provides a convenient means of implementing an object-oriented architecture in a distributed environment.

In the *synchronous* message-based semantic, three primitives are employed for inter-process communication and synchronization: *send()*, *receive()* and *reply()*.

The *send* primitive implements the dispatch of a message to a destination task followed by the receipt of a reply from that task. Once it has called the *send* primitive, a task remains blocked until the receipt of a reply from the destination task.

The *receive* primitive is used to receive messages from other tasks and, typically, to wait for signals from interrupt service routines. Tasks which use the *receive* primitive remain blocked until a message or signal arrives, or until a user-determined timeout occurs. The use of the *receive* primitive for the receipt of both messages and signals at a single point of execution considerably simplifies the structure and design of tasks which must simultaneously deal with external events and communicate with other tasks.

The *reply* primitive is non-blocking. It is used by tasks, such as servers, which cannot block while dispatching a message. A *reply* is always made to a task which has used the *send* primitive to send a message to a given task and is waiting for that task to reply.

Task synchronization is implicit in the communications primitives employed. For instance, a *server* object should never block when posting a message to another task. For this reason, servers employ the *receive* primitive to receive messages from clients and the *reply* primitive to respond to clients. *Courier* objects are used to carry messages between servers, as a server would block if it employed the *send* primitive to communicate directly with another server.

A synchronous message-based semantic may be constructed from the more primitive inter-process communications semantics offered by operating systems such as VMS or VxWorks, or it may be obtained as the native semantic

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The Transmission of Accelerator Timing Information around CERN

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Abstract

Prior to the construction of the Large Electron Positron (LEP) collider, machine timing information was transmitted around CERN's accelerators using a labyrinth of dedicated copper wires. However, at an early stage in the design of the LEP control system, it was decided to use an integrated communication system based on Time Division Multiplex (TDM) techniques. Therefore it was considered appropriate to use this facility to transmit timing information over long distances. This note describes the overall system, with emphasis placed on the connectivity requirements for the CCITT G.703 series of recommendations. In addition the methods used for error detection and correction, and also for redundancy, are described. The cost implications of using such a TDM based system are also analyzed. Finally the performance and reliability obtained by using this approach are discussed.

I. INTRODUCTION

In the planning phase of the LEP collider it was recognized that the much greater physical size of LEP compared with previous accelerators would result in a radical change in the way communications systems of all types would be implemented. The larger size implied correspondingly longer cables and more signal regenerators, and consequently much more expense. Moreover, most cables had to be routed through the LEP tunnel itself, significantly limiting the space available for future exploitation of the tunnel. It was evident that the number of cables would have to be reduced by multiplexing information for several different users onto one cable. Consequently, it was decided to install a multiplexed system throughout LEP as a general user facility.

II. ACCELERATOR TIMING SYSTEMS

A. General Features

Typically, computer control systems have a real-time response in the order of 10 to >1000 ms. Whilst this is adequate for many applications there is always a need to trigger selective hardware equipment with a finer time resolution. This is achieved by means of a timing system.

An accelerator timing system is simply a fast broadcast message transfer system. The messages (events) are normally short (typically less than 32 bits) and should have a maximum time resolution of 1 ms. The jitter of each message is determined by the transmission medium and by the sampling processes at the generator and receiver. Depending upon the type of machine, the events are either pre-programmed, according to the specific machine cycle, or triggered by external stimuli, such as emergency beam dump.

A principle difference between a timing system and a control system is that when a transmission error is detected, the control system normally retransmits the message. This is inappropriate with a timing system as, inherently, the message contains a timing reference.

Although the timing and control systems may be considered as two separate identities they are in fact strongly coupled to the machine that they are controlling. For this reason timing systems have always been designed in-house and tailored to the specific accelerator concerned. This implies producing timing equipment compatible with the chosen control system. Equipment of this type is normally not available commercially.

For a large accelerator a typical timing system consists of three parts:

- a central timing generator
- a long distance transmission network
- a local distribution system.

The timing system chosen for LEP and subsequently used on the SPS has been described elsewhere[1]. This article concentrates on the long distance transmission network.

B. Long Distance Transmission

In the case of CERN's Super Proton Synchrotron (SPS) machine, "long distance" refers to the distance between two adjacent auxiliary surface buildings located above the SPS tunnel. For the LEP machine it refers to the distance between two adjacent tunnel alcoves. For both scenarios the distance is between one and two kilometers.

For the original SPS machine the accelerator timing information consisted of a 1 ms clock and short (7 bit) trigger messages called events. The events were Manchester encoded and transmitted to each building over a video cable containing two good quality twisted pairs. One pair was used to transmit the 1ms clock whilst the other carried the events. The transmission rate was 333 kbit/s and no error detection or correction was employed. "Tap-off" amplifiers were in-

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Time and Load Measuring in the SPS/LEP Control System

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Abstract

This paper describes the experiences with the SPS/LEP Control System during its first operational days from the communication point of view. The results show difference between hardware possibility of the local communication based on the modern technology and the possibility to use it by PC machines. There is also several figures describing the activity on the communication lines.

I. INTRODUCTION

The control system of the SPS/LEP is based on distributed microcomputer network which contains more then 300 hosts and many thousands of different devices used for the control. Backbone is created by the communication system which can be divided into two parts. The horizontal plane is based on the Token Ring system to which are connected hosts used for control of particular processes on high level and many vertical planes provide connection onto the control devices (computers, interfaces, VME creates, etc.). MIL-1553 B is used here as the standard for the communications.

Such control system is very interesting first of all by its simple design where the total computer power is obtained by the relatively small quantities of hosts (IBM PC clones) and also for the sophisticated combination of a different communications devices (TDM, gateways, bridges, etc.) which ensure flexible services in the large area and long distances (27 km) [1][2].

My activity was concentrated on the Token Ring services and because my programs had to communicate through the whole network it was interesting to know the environment in which I had to work and its basic characteristics as the response time, speed of data transport and the load of the system (from the point of view of communication). Detail results are reported at CERN SL/CO/Note 90-05.

II. NETWORK ACTIVITY

During November and December 1989 when LEP started normal operation and all parts of the control system were working normally I collected some data about the activity of all hosts in the Token Ring communication network of the Control system. The aim of the measurement was to get a general overview of how much the Token Ring network was used by users for real control work.

For this purposes a set of programs were developed which are part of the Network Management System [2]. The results and evaluation of the activity in the network was used mainly to get an overall picture about the use of particular parts of the network and for long term planning.

For described experiment I have used three programs. The first of them collects data from the selected hosts and two others are used for processing and analysing the data and printing reports. The interface counters are used as the basic information. (The counters of the number of transmitted packets and bytes are a part of the standard communication software.) Data is collected by the RPC mechanism by the standard Rply_data program which is running on almost all hosts as a standard server. All the information from the selected ring can be collected in a few seconds.

The analysing program generate 3 tables. The first gives the total overview about the measured values, the second table gives an extract of the most active hosts and tries to express the values in a pseudo graphic form. The third table shows the activity in the time picture (the same data was collected in regular time intervals).

If we have a look on the tables in detail, then the first table contains 5 originally measured values (time in sec., number of input packets, number of output packets, number of input bytes and number of output bytes) for each host. All other values in the table are calculated from these values. As the best representation of the activity of each host I have used the percentage of the total activity in the network. These figures were calculated for each measured value (input packets, output packets, input bytes, output bytes). The last calculated value for each host is the "average speed", it is the activity of the communication interface - sum of the input and output bytes divided by measured time. On the bottom of the table are summary values and an "actual average speed" in the ring.

The second and third table are self-explanatory. An extract of the hosts in the second table is done on the basis of the minimum trash value. In our case the trash value was selected as 1.5%. From the ghraphic interpretation it is immediate to get a picture of the hosts activity (the most used one). The third table shows all hosts but for better reading of the information there are shown only relative values of these hosts in which the activity is higher than the trash value. This table gives a good overview about the "long term behaviour" or the "stability of needed service". (See examples shown in tables.)

III. MEASUREMENTS OF RESPONSE TIME

There are several tools for the network communication but I have used only two of them, FTP or (TFTP) and RPC (Remote Procedure Call). Both tools ar also heavily used in many others applications. My effort has been concentrated on the RPC implemented via Network compiler [5] from the point of view of the normal user. This is because this facility was the principal tool for many programs in the Network Management System which we are developing in our section and also because RPC is a very powerful tool in itself.

Some timing measurement were done in the past. For FTP and transport of short messages by the UDP facility (which artificially simulates the possibilities of real RPC [4]), the work was mainly concentrated on analysing the communications properties of different operating systems. Another study [6] measured response time of an implemented RPC, but

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THE ELETTRA FIELD HIGHWAY SYSTEM

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Abstract

ELETTRA is a third generation Synchrotron Light Source under construction in Trieste (Italy); it consists of a full energy linac injector and a storage ring with beam energies between 1.5 and 2 GeV. The ELETTRA control system has a distributed architecture, hierarchically divided into three layers of computers; two network levels provide communication between the adjacent computer layers. The field highway adopted for the connection of the middle-layer local process computers with the bottom-layer equipment interface units is the MIL-1553B multidrop highway. This paper describes the hardware configuration and the main communication services developed on the MIL-1553B field highway for accelerator control. As an additional feature, typical LAN utilities have been added on top of the basic MIL-1553B communication software allowing remote login and file transfer; these tools are currently used for software development in our laboratory.

I. INTRODUCTION

The ELETTRA Control system is distributed over the about 260 m Storage Ring circumference and 170 m Linac-plus-Transfer Line, with an architecture based on three computer levels (presentation, processing and equipment interface) and two network layers.

High performance UNIX workstations with excellent graphical capabilities are used as operator consoles at the presentation level. The upper layer network, which is based on Ethernet and the TCP/IP communication protocol, connects the control room workstations and the distributed process level computers called Local Process Computers (LPC).

The LPCs, bridging the two network levels, are the "core" of the control system, where all the main application control tasks are executed, acquiring and processing data from the equipment interface level; the ELETTRA LPC consists of assemblies of VMEbus single-board computers (SBC), running the OS-9 operating system. In order to enhance both performances and modularity, a multiprocessor-multimaster architecture has been developed for the LPC, where each board is allowed to take VMEbus mastership and execute its own data transfers.

Separate lower level network branches connect each LPC to the equipment interfaces, called Equipment Interface Units (EIU). Following a definition widely accepted by the control system designers community [1], the term "field highway" is used to indicate the communication system between the local process computers and the interface-level processors.

The VMEbus standard and the OS-9 operating system are adopted also at the EIU level; the typical EIU configuration consists of one microprocessor board associated with several input/output boards of different type.

Exploiting the high performances of the field highway, we have assigned the LPCs with operational criteria, which enhance system design clarity at the same time: 2 LPCs and 48 EIUs are foreseen for magnet power supplies control, 1 LPC and 7 EIUs for vacuum, 1 LPC and 12 EIUs for storage ring beam position monitors, 2 LPCs and 3 EIUs for linac control, etc. A total number of 14 LPCs and 88 EIUs is to be finally installed.

II. THE MIL-1553B MULTIDROP HIGHWAY

In the project of an accelerator control system, the choice of the field highway is strategic: in spite of the growing of standards in the informatics and electronics world, many different solutions are currently used and proposed. The main parameters considered in the choice of the ELETTRA field highway are: communication topology, electrical noise immunity and data integrity, deterministic response, cost and performance. After a careful investigation of the non-proprietary commercially available products, we decided to adopt the MIL-1553B standard [2], slightly modified for accelerator control.

A. Communication topology

The MIL-1553B standard, originally developed for the aircrafts by the U.S. Department of Defense, defines a serial Time Division Multiplexing (TDM) highway on which one Bus Controller (BC) can communicate with up to thirty Remote Terminals (RT) in a multidrop configuration; the BC always provides data flow control and is the sole source of communication. This hierarchical scheme perfectly fits into our control system architecture: placing the BCs and the RTs at the LPC and EIU levels respectively, separate MIL-1553B branches connect each LPC to the EIUs it supervises. A typical configuration is shown in figure 1. Moreover, a multidrop highway topology together with the appropriate communication software permit to add and/or remove EIUs with no system shutdown, catering for future upgrades, requests or simple maintenance.

B. Electromagnetic noise immunity and data integrity

In order to guarantee a very good immunity from the electromagnetic noise of an accelerator environment, a shielded twisted-pair cable is adopted as MIL-1553B highway physical medium on which Manchester II biphase coded differential signals are transmitted.

In addition to that, the following intrinsic "acknowledged message" exchanging mechanism is used to assure data

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Network Communication Libraries for the Next Control System of the KEK e⁻/e⁺ Linac

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Abstract

The network communication libraries for the next control system of the KEK Linac have been developed. They are based on TCP/IP sockets, and show high availability among the different operating systems: UNIX, VAX/VMS, and MS-DOS. They also show high source portability of application programs among the different computer systems provided by various vendors. The performance and problems are presented in detail.

I. INTRODUCTION

The KEK 2.5-GeV electron/positron linac has been controlled with a distributed processor network since its first operation in 1982 [1,2]. Since, however, the system resources have become inadequate for increasing demand, we have introduced several subsystems in order to extend the system capability [3]. Furthermore, we have studied the possibility of system rejuvenation by a complete replacement of the minicomputers and their associated fiber-optic network with new ones. The proposed next control system comprises Unix-based workstations as a man-machine interface, an Ethernet as a high-speed communication network, and VME stations as front-end systems [4].

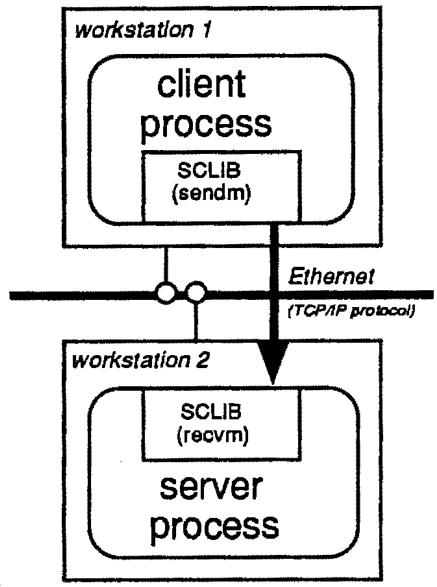
It is apparent that the tools for communication between workstations and VME stations are needed in the proposed system. In addition, some of the subsystems (the operator's console subsystem which comprises DOS-based personal computers [5], a diagnostic expert system for the linac injector developed in a Unix workstation [6], a beam-current monitor developed in a VAXstation [7], and so on) are expected to be used with the next control system. Thus, communication availability between different operating systems is important in our case.

We have developed a network communication library called "SCLIB" for the media of Ethernet with the TCP/IP protocol. Details are described in section II. Another library used to control the magnet power-supplies in the KEK linac, called "MGLIB", has been developed as an improved version of the SCLIB. The features are demonstrated in the section III. A discussion related to these libraries is presented in section IV. We hope that our present experience will provide good guidance for those who intend to introduce a similar network communication system.

II. NETWORK COMMUNICATION LIBRARY

A. Principles for the Library

The library "SCLIB" has been developed for the TCP/IP protocol. It was designed as a tool for real-time data transfer between processes, which is different from a file-transfer tool (like FTP), a file-sharing tool (like NFS), and an




```
main() /* client process */
{
 int sc_open(), sendm(), sc_errend(), sc_close(); /* sclib */
 extern int sc_errno; /* error code holder for sclib functions */

 sd = sc_open( "service_name@nodename" ); /* open connection */
  if( sc_errno < 0 ) sc_errend(); /* error message & exit */

 rtn = sendm( sd, "message" );     /* send a charcter string */
  if( sc_errno < 0 ) sc_errend();

 sc_close( sd );                   /* close connection */
}
```

Figure 1
Example of transferring a character string from a client process (workstation 1) to a server process (workstation 2). The basic flow of the SCLIB function calls is also shown.

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A Program Development Tool for KEK VME-MAP Control System

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Abstract

The control system for KEK 12 GeV Proton Synchrotron has been replaced with a distributed VME-bus based microcomputer system and a MAP local area network. In order to simplify programming for network application tasks, a set of a preprocessor for a PASCAL compiler and a network communication server has been developed.

Application programs for accelerator control system have blocks with similar codes; sending, waiting for, receiving, analyzing messages, etc. The preprocessor called "OBJP" incorporates such common codes into the source code written by an application programmer.

In case of a simple program, the size of the source code is reduced by one tenth of a full coding.

I Introduction

The present control system for the KEK 12GeV PS has been modified by using VME-bus based computers and MAP local area network. On these computers, application tasks work under the VERSAdos; real-time multi-tasking operating systems. In this case, tasks in one group run on some computers and they communicate with each other by network. Then, most important factor of such programs is that any programmer can write the communication function of applications easily. By reason of these thoughts, the network support programming tool 'OBJP' has been created.

The 'OBJP' is preprocessor of PASCAL compiler, but the source file of OBJP programming seems to be a new language system like PASCAL.[1] And it also seems like the object oriented programming, but 'OBJP' is not complete object oriented programming. So the 'OBJP' is a communicatable multi-tasking program development tool. But we think that both the 'OBJP' applications and object oriented programming found on a same basic idea; each function is isolated and communicate with each other by message.

Let's show the 'OBJP' programming, and the configuration of the VME-MAP computer system for the 12GeV PS control.

II System configuration

This control system consists of two major devices; 26 VME-bus computers and a MAP local area network.[2] All the VME-computers are linked together in the same level. Their physical connection is bus style, but logical connection is ring style by token-passing. All computers are equal to each other in the logical ring.

Each computer dedicates to each specialized function. There are computers of one network manager, one program development, four console and many device controllers as shown in fig.1.

The network manager is "UNIX", which checks computer condition and makes logging of its information. The computer "ROLA" offers multi-user programming environment, and sends applications to other computers at rise-up of the computer. The console computer works for human interface. The device controllers control the power-supplies and monitor their status.

Video information signals are also transmitted through the MAP network cable.

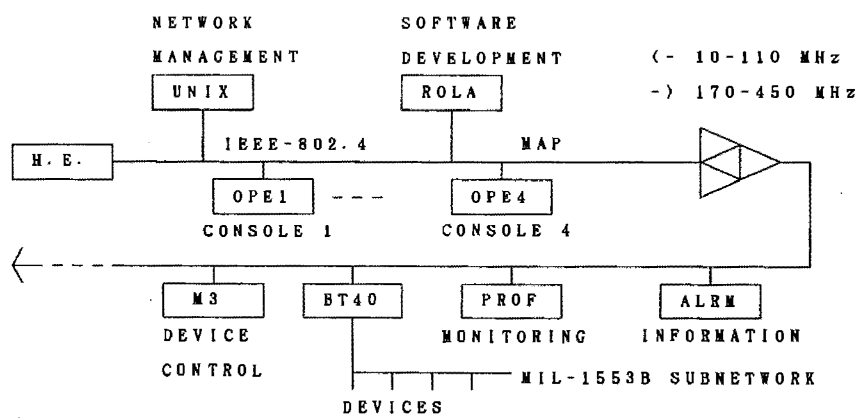

Fig.1 A scheme of MAP-VME control system.
The computers are connected with the MAP local area network.
The head end remodulator(H.E.) repeats signaling from the reverse channel on the forward channel.
Each box shows a computer and ID named after the function
There are some broad-band amplifiers.

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Network Performance for Graphical Control Systems

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Abstract

Vsystem is a toolbox for building graphically–based control systems. The real–time database component, Vaccess, includes all the networking support necessary to build multi–computer control systems. Vaccess has two modes of database access, synchronous and asynchronous. Vdraw is another component of Vsystem that allows developers and users to develop control screens and windows by drawing rather than programming. Based on X–windows, Vsystem provides the possibility of running Vdraw either on the workstation with the graphics or on the computer with the database. We have made some measurements on the cpu loading, elapsed time and the network loading to give some guidance in system configuration performance. It will be seen that asynchronous network access gives large performance increases and that the network database change notification protocol can be either more or less efficient than the X–window network protocol, depending on the graphical representation of the data.

I. Introduction

Performance is one of the considerations when configuring computer control systems. Other considerations are equipment and software costs. In order to help our customers to make intelligent decisions we have made some initial performance measurements on network real–time database access for both synchronous and asynchronous remote access, as well as some measurements to compare network database change notification against network X–protocol for graphical data presentation.

II. Vsystem's Real–Time, Networked Database

Vaccess is the real–time database component of Vsystem [1]. A library of access routines allows for full access to the run–time database. Routines are included to search the database in various ways and to request and cancel change notification by wake–up or interrupt routine (AST) execution. The library of access routines handles the network transparently to the user. Network access can be either synchronous or asynchronous.

With synchronous access to a remote database, the program making the Vaccess routine call will not continue execution until the request has been sent over the network and a reply received, a process that can take many milliseconds. The network messages contain few useful bytes leading to inefficient cpu and network utilization.

With asynchronous access, a program can make many calls and then call a wait routine, at which point the program will not continue execution until all the calls have been completed. Not requiring an immediate answer means that the Vaccess routines can include many, if not all, the remote database access requests in a single network packet with a consequent dramatic increase in cpu and network utilization.

The arrival of X–windows and X–terminals has recently given the implementers of graphical control systems more configuration options. One can use workstations all running the graphics software and all accessing the data over the network, or one can use a single, powerful, processor running a single copy of the graphics software and serving the users at X–terminals. Both configurations have advantages and disadvantages. Here we attempt to quantify the network issues in this choice.

III. Remote Database Access Measurements

Vsystem supports VAX/VMS and VAX/ELN. All of these measurements were made between two VAXstation 3100 model 30 workstations rated at 2.7 VUPs, running VAX/VMS V5.4–2, current VAXstations have performances about four to five times that of the VAXstation 3100 model 30. It is important to note that these measurements were intended to compare the different protocols and they can never replace benchmarks on the proposed computers as many factors affect the system performance apart from the cpu rating.

The network protocol used by Vsystem in these measurements was DECnet. The test consisted of a program running in one VAXstation 3100 model 30 which called multiple "RPUT"'s and "RGET"'s to a database channel in a database on another VAXstation 3100 model 30. "RPUT" and "RGET" are Vaccess library calls to put and get a real number to and from a channel. Standard VMS library calls were used to access the elapsed time and cpu time, and VMS NCP was used to report the network bytes and messages.

Table 1 on the following page lists the measurements made for 1000 calls. Measurements for larger and smaller numbers of calls scaled with the measurements in Table 1.

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A New Approach in Development of Data Flow Control and Investigation System for Computer Networks

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ABSTRACT

This paper describes a new approach in development of data flow control and investigation system for computer networks. This approach was developed and applied in the Moscow Radiotechnical Institute for control and investigations of Institute computer network. It allowed us to solve our network current problems successfully. Description of our approach is represented below along with the most interesting results of our work.

INTRODUCTION

Seven years ago we started the development of a new control system for an experimental electron accelerator in our institute. It was planned at the beginning to apply six computers PDP 11/70 and six computers PDP 11/23. These computers were interconnected by lines DL KI/SI (These lines were developed and manufactured in the USSR. The throughput is about 500 kbit/sec). The operating systems are RSX11M/S.

The main our problem was a choice of network software. In that time we knew the DECNET and the so called ALISA, and had two class of software simultaneously on each computer. One week we used DECNET and next week ALISA. The DECNET is a more powerful network package, but the main problem for us was a limited size of available operating memory. First of all it is valid for PDP 11/23. The compromise was as follows: ALISA as a first step, and DECNET for our perspective, when we will get a more powerful computers.

OUR PROBLEMS

It was planned to control the accelerator from a dedicated console. Console consists of four graphical stations. Each graphical station is a ordinary network node (from viewpoint of network service). In addition one computer was planned for a database management. And the first task for us was to investigate application efficiency of network graphical stations and network database. At that time first users of our network appeared. This period is characterized as a period of development and debugging of software for accelerator automation. Terminals and computers were placed in different rooms. And often the main problem for users was to find a free terminal. If free terminal was connected to another computer he used either virtual (remote) terminal service or virtual disk. Also network services were used for transfer of files, and copying of disks and magnetic tapes. In addition another problem for us was the development and enhancement of our network. Many colleagues from other experimental systems asked us to connect their computers to our network for use of graphical stations, plotters, densitometer. Figure 1 illustrates a structure of our computer network (1988). And the vital problem for us was the creation tools for network investigations to solve correctly all our problems.

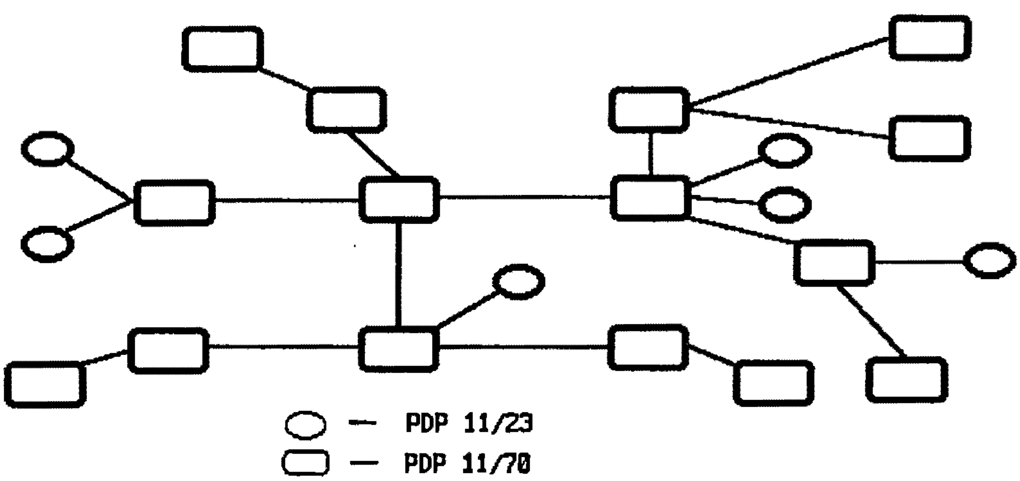

Figure 1. Network structure (1988).

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Concurrent Control System for the JAERI Tandem Accelerator

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Abstract:

Concurrent processing with a multi-processor system is introduced to the particle accelerator control system region. The control system is a good application in both logical and physical aspects. A renewal plan of the control system for the JAERI tandem accelerator is discussed.

Introduction

Progress in the micro electronics region makes real concurrent(parallel) processing reasonable for various applications today. In the logical aspect, a control system of a particle accelerator is a combination of many processes concurrently working for control and monitoring. This implies that the control system may be a good application of the concurrent processing. In the JAERI tandem, we are working to renew the computer control system. A multi-processor system and concurrent programming language will be used in the new system.

Concurrent processing in the control system

We can treat a control system of a particle accelerator as a set of processes to monitor and to control many devices. They have different tasks(roles) weakly coupled with each other. We can depict the system with a model of processes communicating with each other by message transmission, called communicating process architecture(abbreviated as CP architecture)/1/. A concurrent programming language based on the model simplifies programming of the control system, because of easy description of the intrinsic concurrency and communication in the system.

On an usually available multi-tasking operating system, it is possible to describe the above concurrency. But it is not practical because of the overhead to manage too many processes and communications. Thus we must divide the processes only at a moderate level and convert many concurrent processes to several sequential programs in the actual implementation. The resultant programs are difficult to understand. The multi tasking operating system is not ideal for the above modelling.

The merit of concurrent programming is enhanced by use of multi-processor. The concurrent program distributed on multiple processors can give us dramatical merit of performance, because computing power of the multi-processor is proportional to the number of processing elements. It depends on the concurrency of the application(explicit or implicit) and current state of the computer technology. Digital Integrated circuit technology is advanced to increase density of circuits and the performance. Today, high-performance micro processors are available with a low cost.
Well organized multi-processor system has good cost performance ratio.

Communications are important in the system. They are ones between processors and ones between processor and external elements. Not only high transfer rate of the data, but also short leading time are necessary to get good response.

We are interested in Transputer/2/, OCCAM/3/,/4/ and CP architecture as a base. OCCAM and transputer were developed together by INMOS limited as parallel programming language and micro-processor to execute the concurrent program respectively. Both are commercially available with a program development system.

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Palantiri:
A distributed real-time database system for process control.

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Abstract

The medium-energy accelerator MEA, located in Amsterdam, is controlled by a heterogeneous computer network. A large real-time database contains the parameters involved in the control of the accelerator and the experiments. This database system was implemented about ten years ago and has since been extended several times. In response to increased needs the database system has been redesigned.

The new database environment, as described in this paper, consists out of two new concepts:

• A *Palantir* which is a per machine process that stores the locally declared data and forwards all non local requests for data access to the appropriate machine. It acts as a storage device for data and a looking glass upon the world.

• *Golems*: working units that define the data within the Palantir, and that have knowledge of the hardware they control.

Applications access the data of a Golem by name (which do resemble Unix path names). The palantir that runs on the same machine as the application handles the distribution of access requests.

This paper focuses on the Palantir concept as a distributed data storage and event handling device for process control.

I. INTRODUCTION

The National Institute for Nuclear- and High-Energy Physics (NIKHEF) operates for about ten years a linear medium-energy electron accelerator (800 MeV). Currently the accelerator is extended with a pulse-stretcher ring. At the same time the experimental facilities are renewed and according to the plans the first experiment with this new set up will start in the summer of 1992.

All these facilities are controlled by a number of computers running a home made real-time operating system in a point to point communication network and a number of Unix based machines (ref[1]). To prevent possible conflicts all hardware control is performed under the supervision of a device, which historically is called a database, in which all values are stored before they are sent to the hardware. This database was designed ten years ago, uses one (real-time) machine as central storage device. Although this system is functioning well and has proved its reliability in the past years, it has some disadvantages: it offers two different way to access data (by name, and by number), changing its layout is cumbersome and maintaining it appeared to be quite difficult.

Obviously, we wanted something new. This paper describes the aims, the concept and some details of the implementation of the new system. In the last section the current status of the project and plans for the future are discussed.

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Intelligent Trigger by Massively Parallel Processors for High Energy Physics Experiments

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Abstract

The CERN-MPPC collaboration concentrates its effort on the development of machines based on massive parallelism with thousands of integrated processing elements, arranged in a string. Seven applications are under detailed studies within the collaboration: three for LHC, one for SSC, two for fixed target high energy physics at CERN and one for HDTV. Preliminary results are presented. They show that the objectives should be reached with the use of the ASP architecture.

I. Introduction

High luminosity hadronic colliders (LHC & SSC) will require novel detectors, both highly time-sensitive and selective. Potentially, Megabytes data will be produced at rates (66 MHz at LHC) that are beyond performance of today modern transmission and recording technology. From this huge amount of information, however, only a tiny fraction is possessing any real interest. The required high selectivity is assumed to be achieved by a two steps procedure. A first-level decision based on simple "hard-wired" logics can provide significant rate reduction, it leaves, however, for the second-level decision so complex patterns which require a detailed analysis similar to what is done today in off-line programmes, but with an event frequency of typically 100 kHz. Such decisions, based on a huge number (10 to 100 Mbytes) of digitised local or global data coming in a narrow time window, will require the fast execution of precisely tuned algorithms in extremely fast computer-like devices. Industry and computer science make serious efforts in this field. The MPPC (Massively Parallel Processing Collaboration) is concentrated on problems that are likely to benefit from massive parallelism of SIMD type. Such massively parallel machines operate with thousands of processing elements, all highly integrated and controlled under a single controller. Taking advantage of the application needs and of the coincidence between technological opportunities - the development of a new kind of SIMD machine by ASPEX Microsystems (UK): the ASP (Associative String Processor [1]) and the continuous improvement in silicon integration (VLSI/WSI) - a Research and Development programme "The MPPC Project" has been launched [2-5] between ASPEX (UK), CERN (CH), CEA/CEN-Saclay and CNRS/IN2P3-LAL-Orsay (F), as main partners, and EPFL-Lausanne (CH), University of Brunel (UK), University of Geneva (CH), CRIP/KFKI Budapest (H) and Thomson-TMS (F), as associated partners. The applications are dominated by but not exclusively driven by the problem of triggering events in HEP; EPFL, as MPPC partner, is indeed working on a first application in image processing for HDTV. More generally, it can be expected that the same basic processing elements will find their way into quite different application fields. Indeed, the almost infinite scalability of the ASP architecture[1] and its impressive performance targets (in terms of cost, power and achieved density) will attract other suitably parallelized projects (e.g. relational data processing, simulation, computer vision, cellular automata, neural networks) in applications such as, high-definition TV, autonomous guiding vehicles, artificial intelligence, medicine, space science, meteorology, plasma physics, etc. Even one can think about possible application for on-line accelerator control.

II. The ASP architecture

The choice of the ASP, as a R & D platform for the Collaboration, was based on the exceptional potentialities offered by this new architecture which allows a wide range of applications.

The main hardware task is to build four ASP machines, one for each main partner, with 16384 APE array, referred to as the "MPPC array". It is based on the existing VASP-64 VLSI ASP chip used for the TRAX-1 machine, another ASP project dedicated for off-line image processing [6,7]. The MPPC-array design allows for maximum processor element density and maximum direct parallel interfacing via conventional electronics to the readout of particle detectors. For this task, dense packages of ASP must be constructed. This is based on a modular design, using hybridation on insulators of the VASP-64 chips. These modules are built by PolyCon (USA) ; they contain a string of 1024 APEs (16 chips) with two parallel I/O per module. These modules will be installed on boards to make 8K strings. Two ASP boards and a low level controller (LAC) in extended VME standard (in order to be compatible with existing industrial modules) are under construction for each 16-K MPPC-Array machine.

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Realtime Aspects of Pulse-to-Pulse Modulation

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Abstract

The pulse-to-pulse modulation of the SIS-ESR control system is described. Fast response to operator interaction and to changes in process conditions is emphasized as well as the essential part played by the timing system in pulse-to-pulse modulation.

I INTRODUCTION

The benefits of pulse-to-pulse modulation in acceleration operating have been described as early as '77 [1]. It is an effective way to increase the overall output of valuable beamtime of one or more accelerators. With beamsharing, rarely all users of the beam will be unable to accept the beam at the same time. If the PPM-handling quickly responds to changing conditions, there will be virtually no dead-time in the machine operating due to inevitable dead-times of experiments, e.g. during new experimental setups.

In a multi-accelerator facility, PPM is almost imperative. Asynchronously running machines, every one of them operating as an injector for the next one, normally have time left between subsequent injections that can be used for experiments.

II CONTROL AND TIMING SYSTEMS

Much has been said and will be said at this conference about the major trends in control systems in the last decade. Most systems recently designed or upgraded are looking more and more similar: Graphic workstations are the operators' I/O tools and software development platforms. The workstations are linked to a communication backbone. Ethernet, Token Rings, or fiber optic links are candidates. The choice rather depends on the distances to be mastered than on technical advantages or disadvantages.

To the same backbone, eventually as subnetworks with bridges in big systems, the equipment control computers are connected, which are mainly VME-, Multibus-, or CAMAC-based.

Extensive use of graphics and CASE tools has made an essential improvement in the operator's and software designers' access to control systems.

The overall trend is from very special systems tailored to the very special task of accelerator control towards more uniform, general purpose systems and the use of standards of the marketplace.

On the process level, however, the special needs of accelerator control, mainly realtime and synchronisation, do still exist or are becoming even more complex. Therefore the functionality of a control system must be biased by a timing system. The diversity of control systems of old has it's evolutionary relic in the diversity of timing systems, which will resist standardisation trends for another while. The more the higher levels in a control system become general purpose (and less realtime), the more process-specific problems must be solved on the lower levels. This is the domain of the timing system, the equipment controllers, and, of course, the equipment hardware. In the trend to general purpose systems the design of the timing system determines the overall performance significantly. The functionality of the timing system may range from simply providing

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Injection Timing System for PLS

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Abstract

The ultimate goal of the PLS timing system is to successfully inject a electron bunch to a predesigned bucket in the Storage Ring.

In the Linac, a pretrigger of 102.8 microseconds prior to the Gun trigger may be required to charge the pulsed divces properly and it should be precisely delayed to synchronize with beam pass at each accelerating column.

To inject the electron bunch, which fully acceleated in the Linac, into a target bucket of SR, the injection kicker magents must be energized to provide the appropriate magnetic field. For the sequential filling of the SR buckets, the appropriate timing delays throughout the entire timing system are programmably controlled by operator.

Introduction

The Pohang Light Source (PLS) consists of two individual particle accelerators all working in concert to ultimately produce the high brilliance X-ray to the experimenters: the Linac and the Storage Ring (SR). Both accelerators are composed of various transient devices like an electron gun, the booster and klystron modulators, injection magnets, and etc. In the Linac, an electron bunch is accelerated up to 2 GeV for full energy injection, while the SR accelerate the particle only to replenish any energy loss by synchrotron radiation.

The Linac rf system is composed of a booster station, 11 high-power klystron modulator and 10 pulse compressors. It's operating frequency is 2,856 MHz. In the booster station, the driving system provides the optimum condition of the drive signal for high-power klystron and the phasing system make the phase synchronization between the electron bunch and the accelerating wave. The function of these system is to get the maximum beam energy and minimum energy spread on the basis of a stable drive sytem and correctly phased high-power wave guide network. The typical output pulse length from the booster modulator is 4 usec. The high-power modulator supplies pulse voltage to the high-power Klystron. It can operate in two mode : an acceleration mode and a standby mode. In the acceleration mode, the output power is delivered to the accelerating column at the time synchronized to beam pass and then the beam is accelerated. In the standby mode, the output power is delayed with respect to the beam passage and has no effet on the beam. Typical specifications of the modulator are 60 pps pulse repetition rate, and 4.4 us flat top pulse width. Meanwhile, the klystron that utilized the pulse compressor require a phase reversal gate. So the PSK on the booster station is used to reverse the phase of 180°. All of these systems are operated very closely through the timing system.

Injection into the SR accomplishes via a Lamberson septum and the kicker magnets. Prior to injection, the storage ring closed orbit is bumped close to the end of the injection septum by four bump magnets. A pulse of electrons is then transported through the injection septum into the SR. After injection, the bump magnets are turned off in a time corresponding to about two orbits of the ring to prevent the stored beam from disturbunce of the kicker field. The newly injected beam then undergoes coherent betatron oscillation about the closed orbit-motion that is rapidly damped by means of synchrotron radiation damping. This process is repeated at the cycle rate of kicker magnet until the desired beam current is reached.

Timing Sequence

The timing sequence is shown in Fig.1,2 to illustrate that many events are initiated by a pretrigger. In this sequence all the transmission delay are neglected for simplicity. It is supposed also to be no delay for the beam from the gun to injection point, where injection point means the bucket into which the electron bunch is transferred. The time between consecutive buckets passsing a fixed point on the SR is 1.9996 nsec because the SR has 468 stable rf buckets into which a bunch of electrons can be injected. One periode of the rf is named a "tic" so a tic

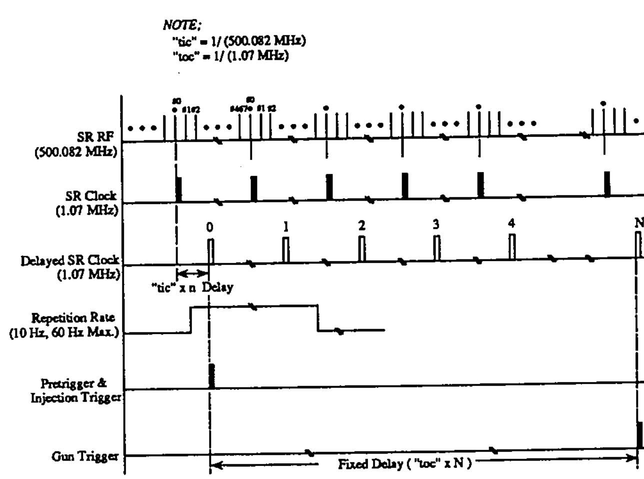

Fig.1 Timing Sequence (I)

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Automated Control System Structure of the USSR Academy of Sciences Kaon Facility

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1. Introduction

Up to date at Nuclear Research Institute of the USSR AS (Moscow-Troitsk) it is finished building of Moscow Meson Facility high intensity current proton Linear Accelerator (LA) (beam parameters: energy – 600 MeV, average current – 0.5 mA, pulse current – 50 mA). The LA proposed to serve as Kaon facility (KF) injector which is under working out [1].

Kaon complex, in addition to LA, includes: buster proton synchrotron (BR) with output energy 7.5 GeV, main synchrotron (SR) with proton energy up to 45 GeV and storer-stretcher (SS). The KF is proposed to work at 3 regimes.

At first regime SS follows SR and is used as beam stretcher. KF time work diagram is cleaned by Fig.1a. A half of beam pulses from LA and BR is used at ones for physical experiments. At second regime SS is inserted between BR and SR and works as collector (Fig.1b.). At third regime it is supposed to store in SS 4-6 beam pulses with next fast exit to experiment (Fig.1c). The such kind using allows to receive terra watt power level pulses ($8 \cdot 10^{14}$ particles with 45 GeV energy) with frequency of 1 Hz. There are presented below brief description of KF systems, which are concerned of radiotechnical systems (RTS) control (ACS) and adjusting (AAS).

2. RTS Interaction

KF RTS can be divided on 3 groups.

The first group unites RTS, which take parts immediately in technological process. The systems work in real time scale and are controlled with the help of devices with early loaded programs, which operate according to ACS

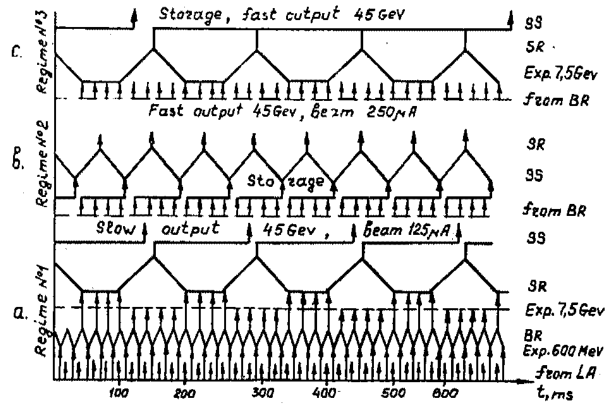

Fig 1. Time regimes of Kaon complex Work

system corrections as a result of diagnostics and measurement systems function. Besides of software there are used also hardware AAS with feedback.

The second group unites measurement and diagnostics systems generally.

The third group includes ACS equipment.

The special features of RTS control depends on two KF properties:

1) the complex consists of cascade row with which of cascade been working in different regimes with different time changing characteristics;

2) the accelerators are fast recycling and high intensity beam devices.

High accelerating process velocity demands increasing of RTS measurement and final-control devices fast-responsibility, localizing of control systems near by the first group RTS and using of distributed control systems. These demands are complicated also by high beam intensity: it needs of accelerators resonator beam loading compensation and coherent betatron particles oscillations suppressing.

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The Development of RF Reference Lines and a Timing System for Japan Linear Collider

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Abstract

The main linac of Japan Linear Collider(JLC) will be operated at an X-band frequency of 11.424GHz. The positioning of the X-band accelerating structures at JLC requires precise phase synchronisation over about 10km. Temperature compensated fiber optic cables will be used for the transmission of the 11.424GHz RF signal. The performance of this transmission line is described. Many timing signals will be also transmitted from the main control room, in which the master RF frequency generator will be situated, via this 1.3μm single mode fiber optic link. The outline of the timing system for JLC is given in this paper.

I. INTRODUCTION

A. General

Japan Linear Collider(JLC) is a future project and an electron-positron collider for the energy frontier physics in TeV region. In order to realize the JLC project, we have been discussing for several years on possible parameter sets of the JLC. Fig.1 shows the layout of the JLC according to the parameter set so far obtained[1,2,3].

The main beam parameters of the JLC are shown in Table 1. One of the characteristics of the present design of the JLC is to operate in a multi-bunch mode. The linac accelerates bunch trains where the bunches contained in a train are separated by about 42cm(1.4nsec) and the number of particles per bunch is 2×10^{10}. Fig.2 shows the bunch structure of the JLC.

Table 1 Design Parameters of the JLC

Center of Mass Energy	E[TeV]	0.5	1	1.5
Luminosity	L[cm^{-2}sec^{-1}]	2.2x10^{33}	8.8x10^{33}	1.3x10^{34}
Total Length of JLC	L[km]	25	25	25
RF Frequency	f_{rf}[GHz]	11.424	11.424	11.424
Accelerating Gradient	G_a[MeV/m]	40	80	120
Repetition Frequency	f_{rep}[Hz]	150	150	150
Particles/Bunch	N	1.3x10^{10}	2.0x10^{10}	2.7x10^{10}
Bunches/RF Pulse	N_b	20	20	20
Wall Plug Power	P_{AC}[MW]	30	120	240
Average Beam Power	P_b[MW]	3.0	9.7	19.3
Horizontal Normalized Emittance	ε_{xn}[radm]	5x10^{-6}	5x10^{-6}	5x10^{-6}
Vertical Normalized Emittance	ε_{yn}[radm]	5x10^{-8}	5x10^{-8}	5x10^{-8}
Beam Size at IP	σ_y/σ_x[nm]	4.6/335	3.2/372	2.9/560
R.M.S. Bunch Length	σ_z[μm]	152	112	95
Energy Loss by Beamstrahlung	ΔE/E(%)	5.1	15	15
Circumference of Pre-DR	L_{PDR}[m]	60.1	60.1	60.1
Circumference of Main-DR	L_{MDR}[m]	163.3	163.3	163.3

The JLC timing system is divided into fast and slow timing systems. Fast timing signal transmission system must achieve the timing accuracy within 1$psec$ over the temperature range from 23 to 27°C and over 12.5km from the main control room. For the precise timing signal transmission, a optical fiber cable was developed[4]. This fiber cable showed the reduced thermal transmission delay change less than 10psec/km in the temperature range from -20 to 30°C(average 0.04ppm/°C), which is 100 times smaller than that of any other existing coaxial cables and conventional optical

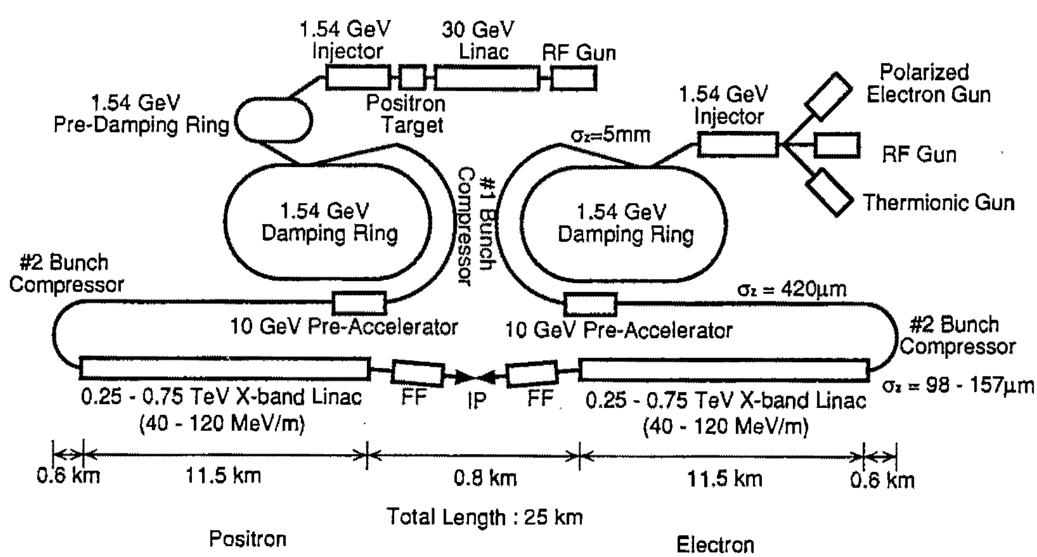

Fig. 1 Layout of the JLC

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A NEW VME TIMING MODULE: TG8

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Abstract

The two accelerator divisions of CERN, namely PS and SL, are defining a new common control system based on PC, VME and Workstations. This has provided an opportunity to review both central timing systems and to come up with common solutions. The result was, amongst others, the design of a unique timing module, called TG8.

The TG8 is a multipurpose VME module, which receives messages distributed over a timing network. These messages include timing information, clock plus calendar and telegrams instructing the CERN accelerators on the characteristics of the next beam to be produced.

The TG8 compares incoming messages with up to 256 programmed actions. An action consists of two parts, a trigger which matches an incoming message and what to do when the match occurs. The latter part may optionally create an output pulse on one of the eight output channels and/or a bus interrupt, both with programmable delay and telegram conditioning.

I. INTRODUCTION

Until the advent of the Large Electron Positron (LEP) collider each new accelerator built at CERN had its dedicated timing system. Each system was tailored to the specific needs of the machine and integrated into the control system. As the working life of a large accelerator spans several decades, it becomes necessary after a certain period to update the control and timing systems. Such an upgrade was applied to the SPS timing system in 1985 [1] and subsequently it was decided to adopt the same system for LEP.

The rejuvenation of the PS control system is presently being implemented [2]. The TG8 timing module, described in this paper, will form an integral part of the joint PS/SPS/LEP timing system. The TG8 is based on a similar but simpler module, the TG3, currently in use at the SPS and LEP.

II. ACCELERATOR TIMING SYSTEMS

The typical real time response of a large accelerator control system is in the region of 10 to >1000ms. Whilst this is adequate for many applications there always remains the requirement to activate equipment with a finer real time resolution. Such an application would be the ramping of the main power converters around LEP. This is achieved by using a separate timing system.

General Machine Timing (GMT) systems for large accelerators normally consist of three parts:

- a central timing generator
- a distribution network
- receiving modules

This article concentrates on the VME receiving modules, although the other two points are also discussed.

The central timing generator is constructed on a single IBM/PC compatible card and is referred to as the Master Timing Generator (MTG). It is basically a large memory which is pre-loaded with machine related timing information for each cycle. At specific times the MTG broadcasts this information over the distribution system. The MTGs for each machine are synchronized to a CERN wide 1ms reference clock.

For the SPS and LEP machines it was decided to use Time Division Multiplex (TDM) techniques, conforming to CCITT Recommendations, to form a backbone for the distribution network. This was adopted due to the long distances involved and also to reduce the number of cables required in the two tunnels. Because of its much smaller size the PS will retain the use of dedicated cables. The overall timing transmission standards used at CERN have been described elsewhere [3].

The receiver modules (TG8s), so named because they have eight output channels, are connected to the timing network and receive information in the form of frames referred to as events. The use and operation of the TG8 is described in more detail later.

III. EVENTS

A. *Standard events*

Standard events mark precise times within a machine cycle, i.e transition, start fast extraction, end of flat top etc. In particular, they are used to initiate actions in the TG8 action table. Such an event has a "header", identifying it with a given machine, plus a one byte code specifying which standard event it is. In addition to this, each standard event is also tagged by a cycle type, and the occurrence number of that type in the super cycle, namely the Cycle Number.

B. *1kHz Clock Events*

The 1kHz event is used to synchronize up to seven preceding events which may have arrived during the previous millisecond period. This type of timing frame is thus

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Modular Pulse Sequencing in a Tokamak System.

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Abstract

Pulse technique applied in the timing and sequencing of the various part of the MUT tokamak system are discussed. The modular architecture of the pulse generating device highlights the versatile application of the simple physical concepts in precise and complicated research experiment.

I. Introduction

In experimental studies of pulse plasma devices, timing and sequencing of the various events are an important part of the experiment and requires careful considerations. This is achieved in the MUT (University of Malaya Tokamak) tokamak system [1] by employing modular architecture involving various modules of pulse generating devices [2].

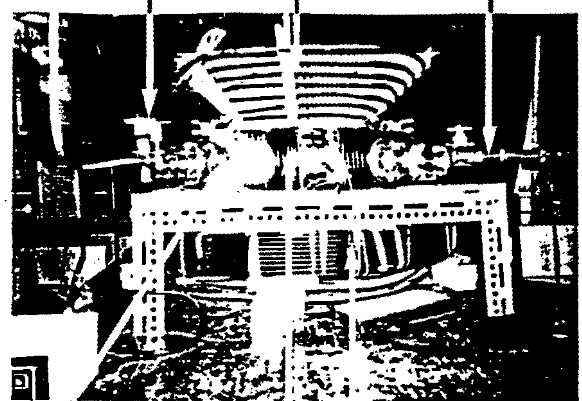

Fig. 1 The MUT system.

II. The MUT System

The MUT system consists of the stainless steel toroidal chamber, the toroidal field coil system and the ohmic heating coil system incorporating the vertical field generating design is assembled as shown in Fig. 1. The major radius of the chamber is 25 cm while the minor radius is 5.4 cm. The torus is divided into two halves separated by insulating flanges. The diagram of the top view of the torus is shown in Fig. 2. The vacuum system uses a 300 litres s^{-1} diffusion pump backed by a rotary pump. The system provides a base pressure of 10^{-5} torr. The toroidal field coil consists of 99 turns of insulated copper wire of total cross-sectional area of 0.3 cm^2, coil resistance of 0.02 Ω and inductance of 95 μH, giving a time constant for the toroidal field of 4.7 ms. It is powered by a 4.5 mF, 1.3 kV capacitor bank system while the ohmic heating system are powered by a 5 μF, 20 kV capacitor bank. The block diagram in Fig. 3 shows the sequence of operation of the various stages.

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The Timing System of the RFX Nuclear Fusion Experiment

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ABSTRACT

The RFX Nuclear Fusion Experiment [1] in Padova, Italy, employs a distributed system to produce precision trigger signals for the fast control of the experiment and for the experiment-wide synchronization of data acquisition channels. The hardware of the system is based on a set of CAMAC modules. The modules have been integrated into a hardware/software system which provides the following features:

- generation of pre-programmed timing events
- distribution of asynchronous (not pre-programmed) timing events,
- gating of timing event generation by Machine Protection System,
- automatic stop of timing sequence in case of highway damage,
- dual-speed timebase for transient recorders,
- system-wide precision of $\leq 3\ \mu s$, time resolution $\geq 10\mu s$.

The operation of the timing system is fully integrated into the RFX data acquisition system software. The Timing System Software consists of three layers: the lowest one corresponds directly to the CAMAC modules, the intermediate one provides pseudo-devices which essentially correspond to specific features of the modules (e.g. a dual frequency clock source for transient recorders), the highest level provides system set-up support

The system is fully operational and was first used during the commissioning of the RFX Power Supplies in spring '91.

1. SIGMA

The Timing System is part of the fully computerized system for experiment control, monitoring, and data acquisition known as SIGMA (Sistema di Gestione, Monitoraggio ed Acquisizione Dati) [2]. SIGMA employs two distinct technologies: PLCs and CAMAC/VAX systems. Nine large PLCs, grouped into four subsystems provide slow control and continuous monitoring of the corresponding machine subsystems. Fast data acquisition and the generation of the precision trigger signals and of the fast reference waveforms is implemented by means of CAMAC equipment connected to a central VAXcluster via a fibre optic CAMAC Serial Highway implementation. All components of the system are connected to the same fibre optic Ethernet.

* under contract from Hahn-Meitner-Institut Berlin GmbH, Berlin , Germany

\+ now with SPIn s.r.l., Milano, Italy

2. Timing System Hardware Components

2.1. *The Timing Highway*

The CAMAC modules of the timing system are connected by a single optical fibre Timing Highway which carries the timing events in encoded form, imprinted on a 1 MHz carrier clock. Each timing event is encoded in a 10-bit frame. The fibre and connector are identical to the ones used both for the fibre optic Serial Highway and for the fibre optic Ethernet.

2.2. *CAMAC Modules*

The system employs three types of CAMAC modules which provide the following functions:

The *Encoder Module* generates encoded timing events; it can be seen as the input device of the Timing system. Each Encoder can generate a maximum of seven events, of which six are produced by hardware inputs and one by software command. The event inputs are priority encoded. The code associated with each event is pre-loaded via the CAMAC interface.

The *Decoder Module* is the output device of the Timing System. The module can be divided in two sections: the code-recognizer section, which matches encoded events traveling on the Timing Highway to pre-loaded codes held by internal registers, and the counter-timer section. The module contains a crystal oscillator, which can be used as master clock. The module provides a rich set of options and operating modes

The *Timing Event Recorder* module can log up to 512 timing events together with their relative time of registration with reference to a start event (software or hardware defined).

Encoder and Decoder module have been developed for the Tokamak de Varennes [3]. The Timing Event Recorder has been added by RFX. All modules are commercially available [4].

3. HW System Description

3.1. *Timing Highway Structure*

From an operational point of view, a clear distinction has been made between parts of the timing system which are required to be permanently 'on-line' and which are essential to produce a plasma shot and other parts which could be excluded, intentionally or unintentionally, without preventing normal operation. Hence, the timing system has been separated in two sections: *Machine Section* and *Diagnostics Section* (Fig. 1). The Machine Section delivers timing signals to all the essential machine components, i.e. converter units, gas injection control, essential data acquisition equipment. The Diagnostics

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An Optical Fiber Phase Lock Network of a Radio Interferometer

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Abstract

A new phase-lock network using fiber-optic system was developed as a local signal distribution system for 84 antennas of the Nobeyama Radioheliograph. This network is a open loop system and consists of a master oscillator with an E/O converter, a 1-to-84 optical divider, phase stable optical fiber cables and phase stable phase-locked oscillators with O/E converters. Phase stability of the network and phase noise generated at the O/E converter are discussed. This phase-lock network insures the required phase stability of 3deg/6hours. The phase noise increases the coherent loss of 0.1% at the correlator output, which is very low. This is the first large application of fiber optic devices to an open loop phase-lock network. Our system is very simple and phase-stable. Therefore, it is suitable to the connected array with large number of antennas.

1 Introduction

RF signal transmission systems using optical fibers have advantages of low loss, wide bandwidth and high durability to electro-magnetic interferences. These characteristics are beneficial to long-distance signal transmission. Furthermore, development of a specific optical fiber extended applications of the fiber-optic system to precise timing signal transmission and phase-lock link [1]. At the JPL, a fiber-optic system was tested to distribute a reference frequency to a Deep Space Station, which usually employed coaxial cables [2]. In a VLBI system of the National Astronomical Observatory, Japan, the fiber-optic system is installed to transmit a frequency standard signal from a hydrogen master to a remote antenna. The phase stability was about 55 times better than ordinary coaxial cable transmission systems [3]. At the National Laboratory for High Energy Physics, Japan, a part of coaxial cable link between the 2.5GeV LINAC gun room and the TRISTAN control room was replaced by a fiber-optic system [1]. Another approach using an active phase stabilizer was also developed at the JPL, and it compensated the delay variations using signals reflected at remote units [4]. At the CSIRO, an optical fiber network is installed to the Australia Telescope. This telescope is a radio interferometer with 5+1 paraboloidal antennas of 22-m diameter and a closed loop network with active phase stabilizer is used to lock the phase of local oscillators.

In the radio interferometer, precise measurements of phase among received signals are quite essential to synthesize high-quality images. Although the closed loop phase-lock network is quite stable, its configuration is complicated. As the open loop network has a simple structure, it is suitable for the interferometer with large number of antennas. At the Nobeyama Radio Observatory, a new radioheliograph is now under construction [5]. This system is a radio interferometer for solar observations, which consists of 84 small paraboloidal antennas of 80-cm diameter. These antennas are aligned on a T-shaped baseline of 490m east-west and 220m north-south. In this system, an open loop phase-lock network is installed to synchronize local oscillators. This is the first large application of fiber optic devices to an open loop phase-lock network. The phase stability of the open loop network is sensitive to the phase responses of the devices in the network. In addition, noises generated by the optical devices in the network increase phase noises of local oscillator outputs and degrade the sensitivity of the interferometer. Therefore, we have analyzed the phase stability and the phase noise of this network.

In this paper, we describe the outline of the developed optical fiber phase-lock network and discuss the phase stability and the phase noise of this network.

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Replacing PS Controls Front End Minicomputers by VME Based 32-bit Processors

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Abstract

The PS controls have started the first phase of system rejuvenation, targeted towards the LEP Preinjector Controls.

The main impact of this phase is in the architectural change, as both the front-end minicomputers and the CAMAC embedded microprocessors are replaced by microprocessor based VME crates called Device Stub Controllers (DSC).

This paper discusses the different steps planned for this first phase, i.e:

- implementing the basic set of CERN Accelerator common facilities for DSCs (error handling, system surveillance, remote boot and network access);
- porting the equipment access software layer;
- applying the Real-time tasks to the LynxOS operating system and I/O architecture, conforming to the real-time constraints for control and acquisition;
- defining the number and contents of the different DSC needed, according to geographical and cpu-load constraints;
- providing the general services outside the DSC crates (file servers, data-base services);
- emulating the current Console programs onto the new workstations.

I. INTRODUCTION

The CERN accelerators are composed of two sets: the PS Complex of ten small and fast cycling machines (PS Division), the SL Complex of two big and slow cycling machines (SPS and LEP, SL Division). The rejuvenation of the CERN Proton Synchrotron control system is done on a basis of a common CERN project, aiming at a real convergence between all accelerator control systems. [1] [2]

The first phase of PS control system rejuvenation has started in 1991 for the subset of LPI machines (LEP Pre-Injector). [3] The main impact of the architectural change is the replacement of both front-end minicomputers and distributed CAMAC embedded microprocessors by a set of distributed microcomputers linked on an Ethernet segment with a local file server.

These microcomputers called DSC (Device Stub Controller) are based on both standards PC and VME crate with 32-bit embedded microprocessors. For the PS control system, the VME crates are mainly used. The DSC provides a uniform interface to the equipment and acts as a master and data concentrator for distributed equipment, interfaced via field buses. Due to the large investment in the associated interface equipment, the serial CAMAC loops are kept and their control are done via a serial driver module in the VME crates. [4]

II. BASIC FACILITIES FOR DSC

A. Control System Architecture

The common accelerator control system architecture consists of three layers:

- control room layer with workstations and central servers,
- front-end computing layer distributed around accelerators and based on the DSC,
- equipment control layer with ECA (Equipment Control Assembly) control crates which form part of the equipment.

For the PS Control System the communication between the two first layers, as well as the communication within these layers, is based on a TCP/IP network. The processor of the VME crate has an on-board Ethernet controller as a standard link to the network, and is a diskless machine for reliability [disks proved to be the weak point of the actual LEP PCA (Process Control Assembly)] and because the back-up procedures and management of files and data are supposed to be easier when storage is less distributed. The different programs of the different DSC are centralized on a single server.

B. Choice of a Real-Time UNIX Operating System

The constraints choosing an operating system for the front-end processors were the following:

- the system has to be real-time in order to warranty a predictable response time to external events,
- the same operating system must be available for both VME based MC68030 and PC processors,
- for networking, TCP/IP (with BSD socket interface library) and NFS client are required,
- system must be able to run diskless without swapping,
- shared libraries and data segments are required, as well as source level debugger.

In order to minimize the formation required to develop applications, we had to minimize the heterogeneity between various systems. We had to re-use common facilities developed for the LEP accelerator control (based on Xenix system). This resulted in the choice of the LynxOS real-time

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Device Controllers using an Industrial Personal Computer of the PF 2.5-GeV Electron Linac at KEK

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Abstract

Device controllers for electron guns and slits using an industrial personal computer have been designed and installed in the Photon Factory 2.5-GeV Electron Linac at KEK. The design concept of the controllers is to realize a reliable system and good productivity of hardware and software by using an industrial personal computer and a programmable sequence controller. The device controllers have been working reliably for several years.

I. Introduction

Operators of the Photon Factory 2.5-GeV Electron Linac (PF Linac) were required to reduce the beam tuning time for starting up; therefore, detailed information concerning the accelerator was necessary in order to understand the behavior of the linac. New device control systems, including slit controllers of the beam energy analyzing system and electron gun controllers for the PF Linac, have been installed for improving the operational performance, such as monitoring the electron gun and beam parameters, since 1989.[1)]

If we consider the configuration of a device controller for an accelerator, combining a personal computer and a programmable sequence controller (sequencer) is the best solution. This is because they have the advantage of low-cost and good productivity for a device controller. Furthermore, they are now very popular and reliable, and have many cheap circuit boards and extension units as a digital/analog I/O. A personal computer complements some of the functions of a sequencer, such as the display of data and the management of data/program file. For this reason, industrial personal computers (NEC FC-9801V) and sequencers (OMRON C200H) were employed for the device controllers. The FC-9801V has been improved in reliability, compared with the usual personal computer, like the PC-9801, and can run on BASIC encouraging non-expert programers. On the other hand, the sequencer has also been improved regarding its immunity to bad environmental conditions.

For connecting the device controllers to the PF Linac control system, a communication board with a CPU was developed so as to be used in the industrial personal computer. The board separates communication tasks from the main CPU (CPU of the industrial personal computer), and effectively increases the system reliability.

In this paper, we describe the electron gun and slit controller systems according to the above-mentioned idea, and give a brief description of the PF Linac control system, since these device controllers act as a front-end of this control system.

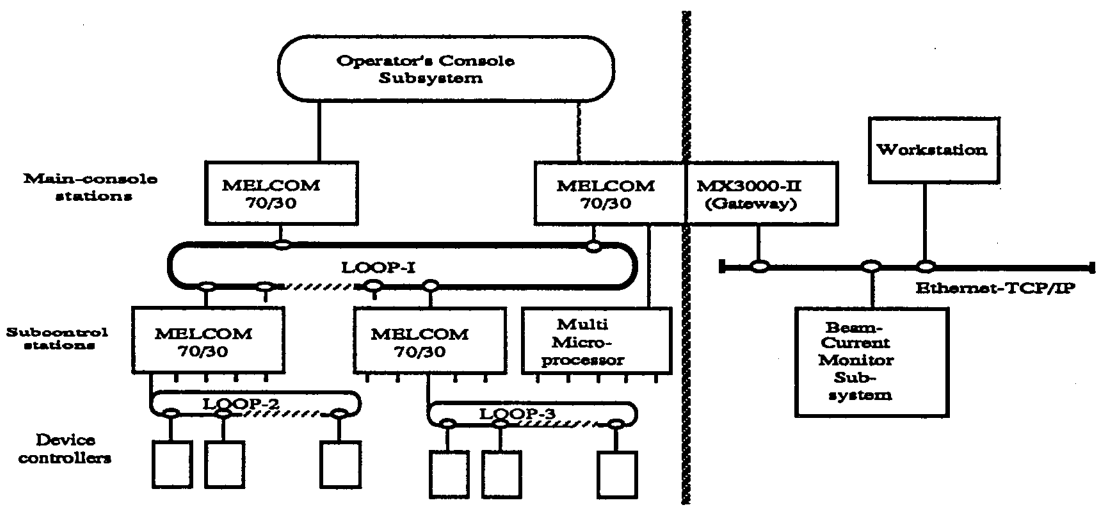

Fig. 1 Block Diagram of the PF Linac Control System

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High accuracy ADC and DAC systems for accelerator control applications.

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Abstract

In the work presented here the ways of construction, the apparatus for the precision measurements and control systems incorporated in the accelerating facilities of INP are considered. All the apparatus are developed and manufactured in the standard of CAMAC.

Introduction

While carrying the experiments on the precision measurements of the mezon masses on the installations with the electron - positron colliding beams one has to use the apparatus of a class 0.001% with the resolution about 0.0001%. An instability of the main power supply sources of magnetic systems of storage rings should not exceed 0.002%.

The powerful RF generators, the controlled sources of power supply with an output power of a few hundred kilowatts, pulse components of electron-optical channels, numerous digital devices including computers are the sources of different kinds of noises. Under these conditions, the stronger requirements on the noise damping are posed to the measuring and control equipment and to the analog data transfer lines.

In the power supply system of the facility VEPP-4 one has to measure of about two thousand points and to form the control signals for more than 500 channels. The time of energy rise is of a few tens of seconds. In the mode of operation one needs the high accuracy matching (0.1% - 0.01%) in the field variation in the magnetic components of accelerators. The technical parameters of the control and measuring structures should provide the operation of the power supply systems both in the static and in dynamic modes of operation.

Digital - to - analog converters

Usually, the power supply sources of the storage ring facilities requires the digital-to-analog converters (DAC) of quite a low fast action at an accuracy ranging from 0.1% up to 0.001%. Therefore, most of the converters used are designed on the base of the pulse width modulation PWM. The advantages of the given type of DAC are well known: the minimum of precise components at a practically arbitrary resolution, high linearity, easily achieved the galvanic isolation of the analog part and consequently, a low price.

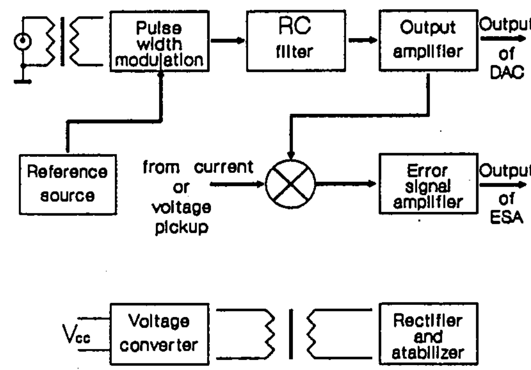

Fig.1. The analog section of PWM-DAC.

One of the popular developments of INP is an 8-channel code-to-duty factor converter (CDFC) located in the crate and transferring the control signal to DAC - PWM integrated directly to the control objects. The DAC signals in the form of different polarity pulse, the distance between carrying the data on reference voltage for control system are transferred through the coaxial cable with the transformer de-coupling to the distance of up to 500 m. The simplified schematic diagram of the converter is given in Fig.1. The pulsed signals from DAC arrive at the trigger controlled by the analog switches. The PWM modulated signal is filtered with the RC filter of the 3rd order. In order to match it with the control system the error signal amplifier (ESA) is envisaged which equalizer the DAC output signal to that from the current or voltage sensor. The galvanic de-coupling on power supply is performed with the help of high frequency converter with the transformer of special design with the minimum crossing capacitance. DAC parameters are: 16 bites, error - 0.01%, settling time - 0.4 s, temperature factor of the output voltage - 0.0003%/K. The given configuration is being widely used in the systems of pulse power supply of the transport channels for charged particles, in the power supply sources for the "high current" correctors, i.e. in those cases, where the controlled objects are distanced considerably and their groundings are

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Driving Serial CAMAC Systems from VME Crates

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Abstract

Large control systems in the 80's were often based on Serial CAMAC loops driven by 16 bit minicomputers. These 16 bit computers, becoming obsolete in the 90's, are advantageously replaced by VME crates. To maintain the investment in Serial CAMAC hardware and software, an inexpensive Serial Highway Driver has been developed which operates in a VME crate as simple I/O module. With this system, both classical configurations, i.e. the Highway Driver on the I/O bus of the minicomputer and the Highway Driver in a so-called CAMAC mother crate, can be replaced with minimal costs and improved performance.

This paper presents a VME Serial CAMAC Driver and compares the performance of the VME driven Serial Highway to the ones driven by minicomputers. The comparison is based on the experience gained with the beginning of the replacement of Norsk Data minicomputers by VME crates in the CERN/PS control system as described in [1].

I. INTRODUCTION

The control system of the CERN Proton Synchrotron complex (PS) is at present based on Norsk Data 16 bit minicomputers which control 26 Serial CAMAC loops connecting approximately 240 CAMAC crates to drive the accelerator equipment. The rejuvenation of the PS control system starts with replacing the minicomputers by VME crates, called Device Stub Controllers (DSCs). The VME computing element is the MVME147 module, performing not only the tasks of the minicomputers but also executing the real-time tasks of the currently used Auxiliary Crate Controllers (ACCs).

The interface between the accelerator equipment and CAMAC has to be maintained for another some 10 years just because the investment in terms of money is so high. This was the reason to develop an inexpensive Serial CAMAC Highway driver as a VME module (abbreviated as SDVME). The first series of 20 SDVMEs have been assembled at CERN but the module is now also fabricated by a major CAMAC/VME manufacturer (C.A.E.N., Viarregio, Italy).

II. DESIGN OF VME DRIVEN LOOPS

The actual Serial CAMAC loops will be rearranged into smaller loops. Every loop is then controlled by one DSC. The new loops consist of up to about 10 CAMAC crates, the number depends on the necessary computing power to control the associated equipment because the CAMAC crates do not house computing elements (the ACCs) anymore. They are not more than simple input/ output devices.

In the present control system, 2 types of CAMAC Serial drivers are used which are now replaced by the SDVME: one on the I/O bus of the minicomputer and one in a CAMAC crate which in turn is driven by a dedicated CAMAC Branch driver. Especially for the latter case which is used in 22 (out of the 26) loops, a considerable overhead of CAMAC equipment and cabling is avoided thus improving reliability, maintainability and equipment access times.

In general, the transmission speed on the Serial Highway of 2.5Mbit/s, bit serial, is maintained. Bit serial transfer permits to continue to use U-port adapters reducing the necessary number of twisted pairs in the Highway cable from 4 to 2 (one for the command, the other for the reply part) and allowing loop reconfiguration. Figure 1 shows the standard configuration. For special cases (instrumentation), the transmission speed is selected to 5Mbyte/s, i.e. byte serial. This is not a problem because in these cases, normally only one CAMAC crate is controlled by a DSC, and the distance is very short.

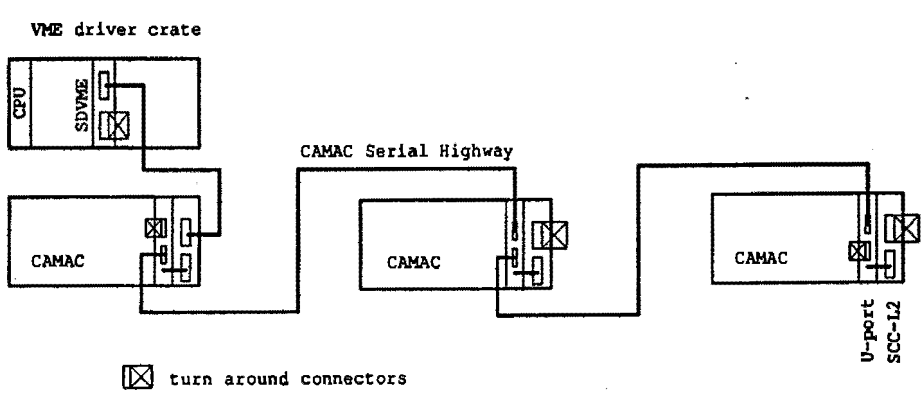

Figure 1. Standard loop configuration

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Fast Automatic System for Measurements of Beam Parameters of the MMF Linac

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Abstract

Fast transverse beam profile and current monitoring systems have been tested at the Linear Accelerator of Moscow Meson Factory. The signals for each system are derived from multiwire secondary emission chamber and beam current transformer. Each beam pulse is digitized by fast ADC's. There are two modes for systems. First one is for detailed beam adjustment and second one is for normal 100 Hz rate of the MMF Linac. Essential features of the hardware, software, data acquisition, measurement accuracy and beam results are presented.

1 Introduction

Systems for automatized measurement of beam parameters are components of general control systems of accelerators. Just through computerized measurement systems feedbacks enveloping accelerator completely or partially are closed [1]. Application of measurement systems permits first of all to make effective tuning of beam parameters such as transverse sizes, emittance and so forth, and, secondly (and it may be the most important) to reduce effects of radiation induced by the beam. This makes essentially easier exploitation conditions and conditions of tuning works, because for getting needful information about the beam it is necessary to spend essentially lesser beam time. Supposed installation in spaces between resonators of the first part of the MMF Linac measuring assemblies, consisting of multiwire electrodes, phase analyzer and target for energy estimation must solve tuning problems to a considerable extent.

In this paper it is considered principles of construction and main features of data treating systems, which permit to get as simple transverse profile of each whole beam pulse in usual exploitation regime as detailed picture of evolution of transverse profile and intensity for single beam pulse, and on the base of this information to estimate mutual influence of neutralization process and Coulomb's repulsion. Besides that high registration speed of profiles and intensity gives the base for hope on getting more full information needful for tuning of accelerator resonators by the beam.

Signals from multiwire chamber [2] and current transformer (Fig. 1) are treated through specialized set of modules and standard CAMAC modules. This set forms flexible enough complex of equipment, organizing the work as with objects placed near computer as with remote ones.

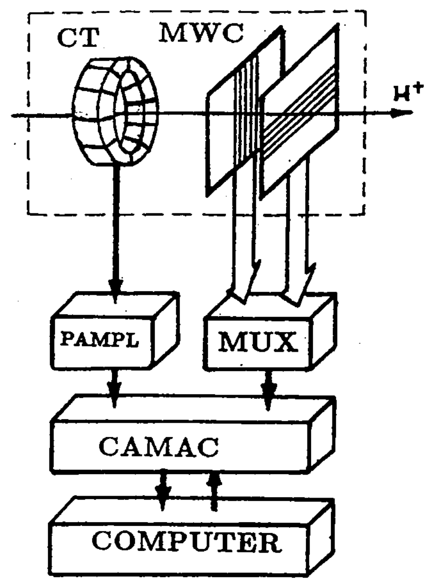

Figure 1: Simplified block diagram of beam parameter measurement system.

2 Speed criterion

Taking into account, that there will be approximately 650 analog signals from the wires placed in proton transfer channel (transfer channel is placed between injector and first accelerating resonator) and in spaces between resonators, it is easy to see, that detailed digitizing of these data by means of separate ADC for every wire is not simple and very expensive way. Therefore construction of system should be made by traditional way of storing and multiplexing of analog data. And criterion of information detailing one must search being attached not only to speed of ADC and computer, but mainly to physical processes

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Beam Position Monitor Multiplexer Controller Upgrade at the LAMPF Proton Storage Ring*

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Abstract

The beam position monitor (BPM) is one of the primary diagnostic tools used for the tuning of the proton storage ring (PSR) at the Clinton P. Anderson Meson Physics Facility (LAMPF). A replacement for the existing, monolithic, wire-wrapped microprocessor-based BPM multiplexer controller has been built. The controller has been redesigned as a modular system retaining the same functionality of the original system built in 1981. Individual printed circuit cards are used for each controller function to insure greater maintainability and ease of keeping a spare parts inventory. Programmable logic device technology has substantially reduced the component count of the new controller. Diagnostic software was written to support the development of the upgraded controller. The new software actually uncovered some flaws in the original CAMAC interface.

I INTRODUCTION

The Beam Position Monitor (BPM) system is the primary tool available for beam tuning at the Clinton P. Anderson Meson Physics Facility (LAMPF) Proton Storage Ring (PSR). The BPM multiplexer controller is an integral part of the BPM system. The multiplexer controller is the interface between the BPM[1] system hardware and the PSR microVAX data acquisition and control system, see Figure 1. There are approximately seventy BPM's that are used as a primary tuning tool by PSR operators.

The existing multiplexer controller was difficult to troubleshoot and repair. The old controller was built on 12 wire-wrap "CASH" cards mounted in a 19 inch rack mount chassis. A spare controller chassis was never built, making on line troubleshooting to the component level necessary.

The analog to digital converters that were used in the original design are no longer available. It should be noted that conversion must occur with in the time constant of the circulating proton bunch in the ring, 360 ns.

In addition, there were no software diagnostic tools to aid in troubleshooting and testing.

Several factors affected design of the new controller. Programmer resources were not available to write code for a more modern microprocessor so we needed to do an Intel 8085-based design and reuse as much of the 3000 lines of original assembly code as possible. The new controller needed to be modular so that "card swapping" could be used as a troubleshooting and repair technique. We wanted to use as many off the shelf components as possible. The new controller needed to be as "plug compatible" with the old controller as possible, so that no modifications to other components of the multiplexer system were necessary.

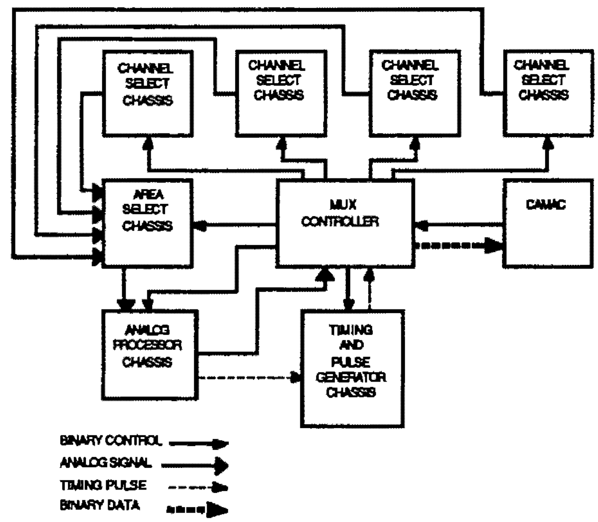

Figure 1. BPM System Block Diagram

We elected to do the project in a STD bus format. STD bus is a mature, well defined, well supported industry standard. The STD bus standard was designed for 8-bit microprocessor control functions, and several vendors offer 8085 CPU cards. In addition, several vendors offer well-built chassis with terminated back planes.

II. CONTROLLER FUNCTIONS

When the BPM control software running on PSR microVAX needs data, it sends a command/request list via CAMAC, to the controller. The request defines which channels are to be read, number of samples per channel, and timing information. The command list is loaded into a CAMAC output FIFO(First In First Out buffer) and then signals the multiplexer controller, via a CAMAC TTL output module, that the FIFO is loaded and ready to be read. The controller reads the FIFO, stores all the command/request information in RAM.

The controller takes a number of actions prior to actual data acquisition. It must first select the channel and area multiplexer that corresponds to the BPM whose position information has been requested. The controller writes to a timing chassis to set up trigger and timing parameters and it writes to the analog signal processor chassis to set gain and

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The KEK PS Fast Beam Loss Monitor System

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Abstract

The higher beam intensities now being accelerated in the KEK proton synchrotron (PS) complex have increased the importance of observing the beam loss during acceleration. The beam loss should be continuously monitored to minimize radiation damage to the accelerator components. A fast loss monitor also is a good tool for observing where and when the beam is lost, by which we are able to get information on the beam dynamics. The development of a fast beam loss monitor system at KEK is described in this paper.

I. INTRODUCTION

The beam intensity in the KEK PS has gradually increased and the PS continuously is operated with an intensity of about $3x10^{12}$ppp. There are, however, some problems in maintaining this intensity in the accelerator and in the beam transport lines. The beam loss might come not only from a miss steering of the beam orbit but also from the short time scale dynamical behavior of the beam bunches. One property of a loss monitor which should be noted is the extremely high signal to noise ratio. In the usual beam monitor systems, the signal is proportional to all of the particles in the bunch. Any loss causing perturbation signal due to some short time behavior of the particles has to be extracted from the signal fluctuation. In a loss monitor, only the perturbed signal is seen.

We have adopted at KEK a secondary electron multiplier vacuum tube as a beam loss detector because of its good time response, compactness and ease of handling. The time response was tested in the TRISTAN electron-positron storage ring which has a bunch length of 300ps. The tube response was quite good, about 40 ns (Fig 1). This time response is good enough to enable turn by turn beam loss monitoring of an individual bunch in the proton synchrotron complex.

As an initial test, thirteen detectors were distributed around the accelerator complex. The PS complex consists of a 750 KeV Cockcroft-Walton, a 40 MeV linac, a 500 MeV Booster and the 12 GeV main ring. There is a transport line between the linac and booster and another line between the booster and main ring. One detector was placed near the 40 MeV transport line, eight detectors were placed around the booster, one detector near the 500 MeV transport line and two detectors in the main ring. The detected signals were digitized by fast CAMAC ADCs and acquired by a VME computer for analysis and display. The control and display software was written using X-windows under UNIX. This enabled simultaneous display of multiple detector signals and the ability to display the data on any X-terminal on the network.

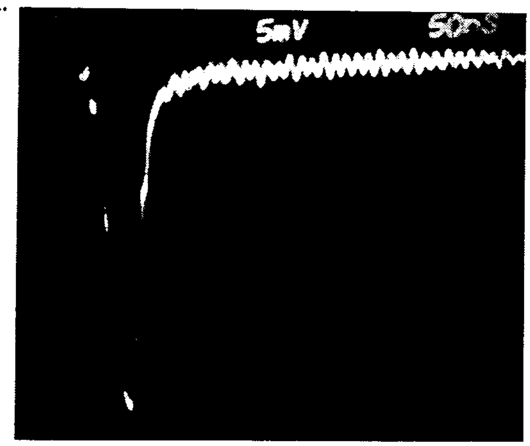

Figure 1. Time response of the detector.

II. HARDWARE CONFIGURATION

A. Detector

The detector is a secondary electron multiplier tube R595 made by Hamamatsu. The gain of the detector is around 10^5 - 10^7. Since the PS loss rate is very high, the tube gain is more than enough. The tube is installed into an aluminum case for light and noise shielding. Attached to the back of

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NON-DESTRUCTIVE FAST DATA TAKING SYSTEM OF BEAM PROFILE AND MOMENTUM SPREAD IN KEK-PS

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Abstract

A mountain view of beam profiles in a synchrotron ring can be taken without any beam destruction by collecting charged particles produced by the circulating beam hitting residual gas in the ring to a sensor. When a rectangular Micro Channel Plate with multi-anodes or lined-up electron multipliers is used as the sensor, the profiles can be measured within one acceleration period, even if the beam intensity is very low and the ring is kept in a high vacuum. We describe this non-destructive profile monitor (NDPM) as well as the momentum spread measurement system by a combination of two sets of NDPM.

1. INTRODUCTION

It is very convenient for beam studies and machine operation to measure the beam profile in a synchrotron ring without causing any damage to the circulating beam. The principal of the non-destructive beam profile monitor (NDPM) is to measure the position dependence of the positive ion current produced by the circulating proton beam in a synchrotron ring. Since the current signal is very low, we usually use an element to amplify the signal, such as a micro-channel plate (MCP) or an electron multiplier (EM). We had installed two sets of NDPM by using a large rectangular area MCP with 32 anodes[1], one of which measures the horizontal beam profile in the Booster ring and another in the Main ring. For setting NDPM at a ring position with a large beam size, using an assembly of many EMs as a sensor, is better than using a MCP, from the view point of long life against radiation and a high saturating signal current[2]. A combination of two NDPMs (one of which is made of EMs and set at the place with a large dispersion function; the another is made of MCP and set at a location with a small dispersion function) is used for measurements of the momentum spread*. We introduce this measurement result in the Main ring.

The VME computer system takes data from those sensors via an A/D converter, rearranges them and displays a "mountain view" of the transversal beam profiles as well as the time dependence of the beam (center, size, momentum spread) within one acceleration period.

2. NON-DESTRUCTIVE PROFILE MONITOR SYSTEM AND DATA-TAKING METHOD

A.Mechanism and electric circuit

A circulating beam in a synchrotron strikes residual molecules in the vacuum ring while producing positive ions and electron pairs with some probability. When a positive collecting voltage is supplied to an electrode (as shown in Figure 1), positive ions move from the bottom to the top along the collecting field. If a large-area rectangular MCP with multi-anodes or lined-up EMs are placed at the end of the field, they can measure the number of ions which are produced in proportion to the beam intensity along the vertical collecting field. In our case, the MCP is a tandem-type and has an effective area of 81mm×31mm; 32 anodes (each anode has a width of 1.5mm, a length of 29mm and a pitch of 2.5mm) are placed closed to the output side of the surface of the MCP. An EM-type NDPM has 30 lined-up EMs, in which every EM has an aperture with a width of 5.2mm and a length of 30mm. Every anode of the MCP or EM has an independent electric circuit (shown in Figure 2).

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A CAMAC-Resident Microprocessor For The Monitoring Of Polarimeter Spin States.

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Abstract: A CAMAC module for the reporting of polarimeter spin states is being developed using a resident microcontroller. The module will allow experimenters at the Indiana University Cyclotron Facility to monitor spin states and correlate spin information with other experimental data. The use of a microprocessor allows for adaptation of the module as new requirements ensue without change to the printed circuit board layout.

I. Introduction

A custom CAMAC module has been developed to allow for the remote monitoring of polarimeter spin states in the Indiana University Cyclotron Facility . The module will provide experimentalists at the facility with data on spin states of the particle beam and allow them to correlate experimental data with this information. The cyclotron control computer sets the polarized ion source by means of a task which also acts as a network multi-node server, providing spin-state data to client tasks on one or more data-acquisition computers, each of which will copy current spin-state data to the module. The standard data-acquisition programs will access the module while reading other event data.

II. Module Functionality

To meet the experimental demands outlined above the module has two eight bit registers for holding the polarimeter states. One register holds the current state and the second register holds the latched state. Most data-taking events read the current state register. For certain CAMAC commands the latched state is read and the current state is moved into the latched state register.

The experimentalist's interface to the module is through seven output LEMO connectors on the front panel of the module. Three connections give the spin data. One connection gives information on what type of particle (proton/deuteron) is being accelerated through the cyclotron. A ready bit, an interrupt bit, and a valid bit are also brought out to the front panel.

A sixteen bit timer countdown register is used in the module. This register counts down in 0.1 second units. This register is loaded by a CAMAC write operation and begins counting down immediately upon being loaded. When the countdown register makes the 1 -> 0 transition the module, current state register, and the valid outputs are cleared.

A sixteen bit sequence number register holds polarization cycle sequence number to permit correlation of event streams from different data acquisition computers. The sequence number register is specified by the data acquisition computer and written to the module.

III. Module Components

i. Microcontroller

To meet the functionality requirements for the module it was decided to use a resident microcontroller. The use of the microcontroller will allow the module to meet the current specifications and give additional flexibility to meet future demands. By using a microcontroller the module can be readily adapted to future uses without the costly printed circuit board redesign that would result from the use of logic circuitry.

The microcontroller that was chosen for this project is the Intel 80C196KC. The chip has a sixteen bit wide internal data bus. Because the registers for the module are specified to be eight or sixteen bits wide the internal data bus for the chip allows for direct, full width register operations.[1]

The module can perform complete operations before the next CAMAC cycle due to a 16 MHz clock.[2]

ii. External Memory

The 196 can take advantage of external memory devices. This features makes the use of external ROM and RAM onboard the module possible.

The module uses three external memory devices. Two 8K x 8 EPROMs are used to hold the code for the microcontroller. The microcontroller accesses the code for its internal operations from the EPROMs. Two chips are used in parallel to allow for sixteen bit wide memory words to be used.

Two 8K x 8 RAM chips are used for external memory register space for the microcontroller. For the functionality of the module as now specified this additional

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High accuracy measurement of magnetic field in pulse magnetic elements

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Abstract

CAMAC module intended for measurements of instant magnetic field using coil sensor is described. It is four channel integrating ADC with current input in which signal integration time is controlled externally and may be optimized for a given signal. Original technical solution allowing to eliminate influence of the integrator capacity and switches instability on overall accuracy is described.

The large accelerator facilities include a great number of magnetic elements interacting with a beam for a short period ranging from 0.01 ms to 10 ms. For example, this class of elements includes all the magnetic components of channels for particle transportation. In addition, most of these elements are operating rarely - once in 1 - 10000 s. For these elements the most optimal is the use of a pulse power supply that reduces the electric power consumption and which is most important, it solves the problem of heat removal. Though, the pulse power supply poses some problems in providing the accuracy of magnetic field and its measurements.

In practice, the measurement problem can be reduced to the measurement problem of instantaneous value of the magnetic field. In fact, the time of the beam-field interaction is usually so short then the field can be taken quasistatic and acting equally on all the portions of a bunch of particles.

There are some elements interacting with a beam for a long time during which the field can be changed substantially. For example, the cyclic accelerators operate in the similar way. But the pulse shape in these elements is determined by the properties of the feeding generator and it is very conservative. The shape relevance can be checked by the point by point measurements while development of such an element and during the operation it is sufficient to control one or two characteristic points (instantaneous value) of a pulse. Usually, the values are measured which correspond to the beginning and the end of the field interaction with a beam.

The inductance sensor proved to be very convenient for the pulse measurements. It can easily allow the shielding and galvanic de-coupling from the facility construction that facilitates substantially the problem of producing the measuring devices.

The experience of operation of the facilities at the Novosibirsk Institute for Nuclear Physics (INP) has shown that at the requirements to the accuracy of magnetic field lower than 0.05% the tuning of' magnetooptic channel was determined by the measurements of fields with these sensors. At higher accuracies one should take into account the deviations between the field (flux) value measured with the help of this probe and the properties of magnetic element as a whole, which are caused by the magnetic temperature variations and some other reasons.

While measuring the instantaneous value the following approach seems to be natural: the field signal is traced with the analog memory device, stored in the memory at the moment of interest and then it is transformed into the code.

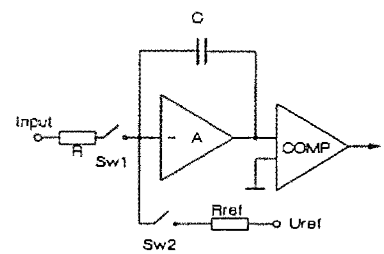

Fig.1. The analog section of module.

The use of the inductance probes enables one quite simple to realize this process with the help of the analog integrator. In fact, the signal voltage from the inductance probe is proportional to the speed variation of the passing magnetic flux:

$$E = W \frac{d\Phi}{dt}$$

Here W is the number of turns of a probe.

If this signal is integrated by the analog integrator, the charge stored in the capacity can be described as follows:

$$q=\int_{t_0}^{t_x}\frac{dE}{R}dt=\frac{W}{R}\int_{t_0}^{t_x}\frac{d\Phi}{dt}dt=\frac{W}{R}(\Phi(t_x)-\Phi(t_0))$$

In this case, the integration limits are given by the moments of connection (t_0) and disconnection (t_x) of the switch Sw1. If the integration is started before the field pulse, the stored charge is equal to:

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FEEDBACK -- CLOSING THE LOOP DIGITALLY

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Abstract

Many feedback and feedforward systems are now using microprocessors within the loop. We describe the wide range of possibilities and problems that arise. We also propose some ideas for analysis and testing, including examples of motion control in the Flying Wire systems in Main Ring and Tevatron and Low Level RF control now being built for the Fermilab Linac upgrade.

I. INTRODUCTION

The standard techniques used to design and analyze analog feedback systems can also be applied to digital systems. It is desirable to consider frequency response, maximum tolerable error, and stability questions for systems controlled by processors. In modern digital systems a considerable amount of software not only replaces analog circuit functions but also allows additional features to be built into the system.

II DEFINITIONS

A. Control System

A control system is generally described as a system that provides an control output variable C in response to an input reference R. This can be accomplished open loop or closed loop. Open loop control means that for a given input, the plant G provides a fixed response regardless of any external loading on the controlled device or process. Closed loop control uses feedback signal H to compare the output to the reference input and generate an error E which is then minimized by the loop.

A predictor of the desired output can be applied to the drive circuit thus producing a feed forward signal. Predictions are normally obtained by computations on a mathematical model combined with measurements of the actual process.

The plant G can be viewed as the combination of fixed drive characteristics plus an equalization, or compensation, filter applied to correct any undesirable behavior. The feedback can be a simple transfer function, such as position to voltage, or a complex filter to aid in measuring the controlled process.

An open loop system is described as the convolution of r(t) with g(t) in the time domain. It is more convenient to analyze these systems in the frequency domain using Laplace transforms. This transforms convolution integrals to multiplication for continuous, linear systems, or C(s) = R(s) * G(s). With feedback, the transfer function is described for the closed loop configuration to evaluate the response and stability of the system. For a closed loop: $\frac{C(s)}{R(s)} = \frac{G(s)}{(1+G(s)H(s))}$

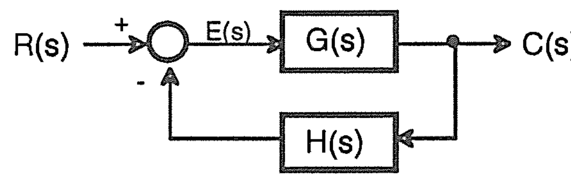

Figure 1. Basic Control System Terminology

B. PID Loops

The most common controller is the proportional - integral - derivative loop (PID). To understand the PID loop we will look at the pieces of a motion control system. When a position change is required the reference input to the system is modified. The system will generate a drive signal proportional to the position error developed between the now changed reference input and the previously held position.

For a step change in the reference input, the drive electronics may allow the motor to far overshoot the desired change. In this case it is useful to consider the first derivative term of the velocity, or acceleration, to maintain stability. This is also referred to as lead compensation.

To correct for long term or steady state errors in the desired output a third, integral, term is included in control loop. This term removes accumulated error over time. This is referred to as lag compensation.

The mathematical formulation[1] for the PID filter in time is: $u_{PID}(t) = K_p e(t) + K_i \int e(t)dt + K_d \frac{de}{dt}$

which transforms to:

$$U_{PID}(s) = K_p + K_i \frac{1}{s} + K_d s$$

$$= \frac{K_d s^2 + K_p s + K_i}{s}.$$

This filter function has one pole at the origin and two zeros that are dependent on the three gain terms.

C. Hardware - Software Equivalents

To implement the PID equation above active elements are used. The hardware is shown in figure 2. Each term is shown as an independent active element however in practice this circuit can be simplified.

While Laplace transforms take us into a convenient domain to analyze analog circuit behavior, the z-transform better serves the transition into sampled time domain.

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Generalized Fast Feedback System in the SLC*

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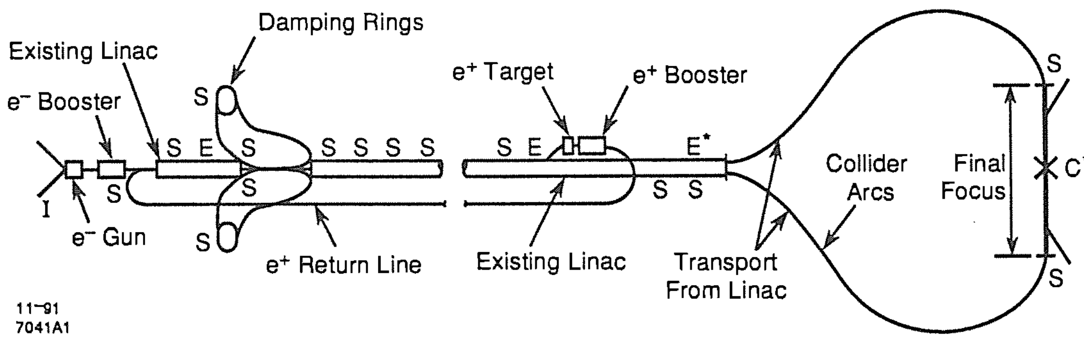

Figure 1: Layout of the SLC with fast feedback loops shown. S = steering loop; **E** = energy control; **I** = intensity control; **C** = special-purpose loop to maintain beam collisions; * = prototype.

Abstract

A generalized fast feedback system has been developed to stabilize beams at various locations in the SLC. The system is designed to perform measurements and change actuator settings to control beam states such as position, angle and energy on a pulse to pulse basis. The software design is based on the state space formalism of digital control theory. The system is database-driven, facilitating the addition of new loops without requiring additional software. A communications system, KISNet, provides fast communications links between microprocessors for feedback loops which involve multiple micros. Feedback loops have been installed in seventeen locations throughout the SLC and have proven to be invaluable in stabilizing the machine.

Introduction

The SLAC Linear Collider (SLC) produces pulsed bunches of electrons and positrons which are accelerated in a LINAC and steered around arcs before colliding at a single interaction point. The maximum beam rate for the machine is 120 Hertz. The SLC control system is based upon a central DEC VAX 8800 and a series of Intel 80386 microprocessors (micros). The micros are distributed geographically, with each micro controlling the devices which accelerate, steer and measure the beam in a region of the machine. The VAX communicates with the micros through a specialized network system, SLCNET, but with the exception of this fast feedback system the micros do not ordinarily communicate with each other.

The feedback system is used for controlling the energy, trajectory and intensity of the beams. The system takes measurements, calculates state functions and implements corrections at a fast rate. It is designed to operate at the beam rate but due to CPU limitations it operates at a lower rate, typically 20 Hertz. Figure 1 shows the SLC machine with currently implemented and planned feedback loops. Prototype feedback systems were initially implemented in three locations for steering, controlling the beam energy [1] and maintaining collisions [2]. These systems quickly became indispensable to the machine operation and an improved, database-driven system was developed to allow easy addition of new loops throughout the machine.

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SMART MACHINE PROTECTION SYSTEM*

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Abstract

A Machine Protection System implemented on the SLC automatically controls the beam repetition rates in the accelerator so that radiation or temperature faults slow the repetition rate to bring the fault within tolerance without shutting down the machine. This process allows the accelerator to aid in the fault diagnostic process, and the protection system automatically restores the beams back to normal rates when the fault is diagnosed and corrected.

The user interface includes facilities to monitor the performance of the system, and track rate limits, faults, and recoveries. There is an edit facility to define the devices to be included in the protection system, along with their set points, limits, and trip points. This set point and limit data is downloaded into the CAMAC modules, and the configuration data is compiled into a logical decision tree for the 68030 processor.

INTRODUCTION

The Stanford Linear Collider includes a number of safety systems that shut down the Collider when unsafe conditions arise. When the Collider shuts down, it becomes difficult to diagnose the cause of the problem. Often it becomes necessary to terminate the startup multiple times before the problem(s) are corrected and safe continuous operation can resume.

Substantially more effective operation would result from a safety system that would report the cause of the fault from the origin of the equipment trip, allowing safe, lower repetition-rate operation to continue, so that the machine can be used to diagnose itself. Automatic return to higher-rate operation after repairs speeds recovery and allows automatic handling of system glitches.

PROPOSED ENGINEERING SOLUTION

A new Machine Protection System (MPS) is being installed in the SLC that will improve machine protection and utilization. The new system will continue to detect unsafe conditions on a pulse- to-pulse basis; however, it will now rate-limit the machine to continue operation at safe levels for diagnostic purposes. This new system utilizes stand-alone array processors to scan the set of fault detectors (radiation, temperature, flows, etc.), making rate limit decisions based on the type and severity of any detected faults, using machine configuration and parameter limit tables developed by machine and radiation physicists.

Facilities have been included to support logging of all machine state changes; the protection system forwards a message to the control room explaining which input signal faulted, and the nature of the fault. These processes allow operators to determine quickly and directly what the problem is/was and what remedial action is required, with a data trail available for later analysis or post-event review.

Beam rate control will be hard wired into the Master Pattern Generator (MPG) and the Injector interlocks used to control the accelerator, so that the machine can be shut down if the expected rates are not properly executed. Failures of sensors or communications failures in sensor processors are treated as if the associated device or included devices where in a worst case failure mode, and appropriate action is taken.

HARDWARE IMPLEMENTATION

The new system will be implemented as a loosely coupled element of the SLC control system, with common facilities on the CAMAC side, new elements built into VME systems, and integrated SLC user interface and applications facilities. As shown in Fig. 1, the system will

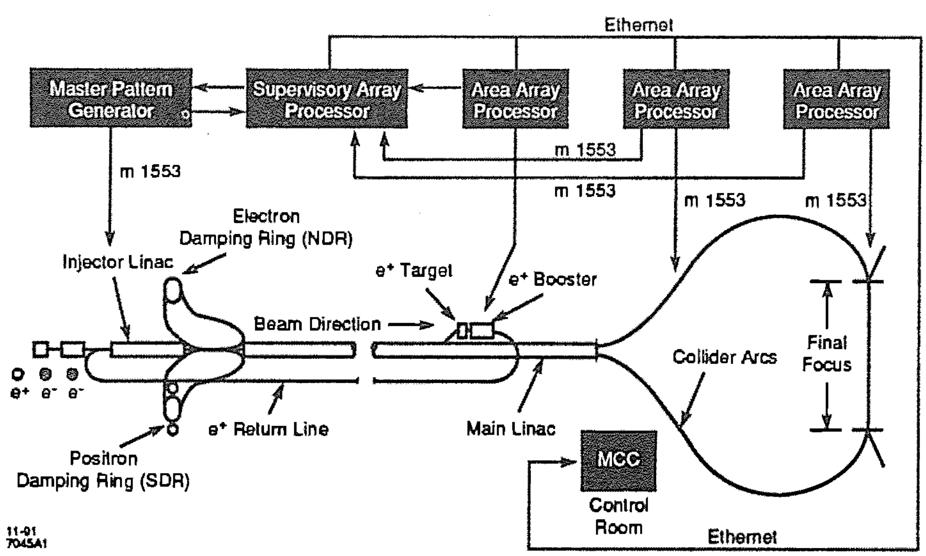

Figure 1.
MPS system architecture.

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FEEDBACK SYSTEMS FOR LOCAL CONTROL OF RACE TRACK MICROTRON RF ACCELERATING SECTIONS

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Abstract.

In order to obtain an electron beam with an excellent energy resolution and stable characteristics, a tight control of the amplitude and phase of the field in all rf accelerating sections is required. The high rf power level, dissipated in the accelerating section (AS), together with temperature dependence of the AS resonance frequency caused the creation of the original control system of resonance frequency. Amplitude, phase and resonance frequency local feedback control system have been designed. All systems are computer conrtrolled analogue single loops. The control loops guarantee stable, repeatable amplitudes (10^{-3} relative error), phases (+/- 0.5^{0}) of the rf fields in AS, resonance frequency of AS (+/- 2 kHz) and have optimal bandwidth. A model of feedback loops has been developed that agrees well with measurements.

I. INTRODUCTION.

The control systems of rf power supply system of the accelerating sections of the continuous wave (CW) race-track microtron (RTM) are described in this paper. These systems operate in different parts of the frequency domain and are connected with each other by control parameters. The described systems ensure constant rf parameters of the AS, such as rf power, resonance frequency and phase difference. These systems form the bottom level of the RTM hierarchical computer control system (CCS) [1]. All analog systems are completely controlled by the top level of the CCS trough optocoupled devices. It is possible to change operating modes and reference signals for feedback control systems by an order from the top level of the CCS.

II. RF SYSTEM.

An outline of the rf power supply of the AS, which is a part of the general rf power supply system of RTM, is illustrated in Fig.1. In an operating mode, a reference rf signal of 2450 MHz (RS) passes over a microstrip rf channel to the klystron input port. The output power of the CW klystron is about 25 kW. The RS is stabilized in frequency up to 1 KHz and in power up to +/- 10^{-3}. The klystron is connected to the AS by a waveguide through the circulator, vacuum window and vacuum port. The incident and reflected waves are checked by means of the double directional coupler (DC) and diode detectors D_1 and D_2. A signal from the rf probe, located in the AS rf power input cell, passes through a 4-channel power splitter to the sensors of amplitude, phase difference, and AS resonance frequency: the detector D_3, the phase detectors PD_1 and PD_2, respectively. The voltage controlled microstrip pin-attenuator A_1 and current controlled phase shifter PS_1 are used as the controllers in the local feedback systems. It is possible to select the operating points of the respective phase detectors with the aid of phase shifters PS_2 and PS_3. Adjusting phase shifters are made as microstrip devices in the form of a meander line on the ferrite layer. They are current controlled, but it is possible to set phase shifters once by special bipolar current pulse train due to the hysteresis

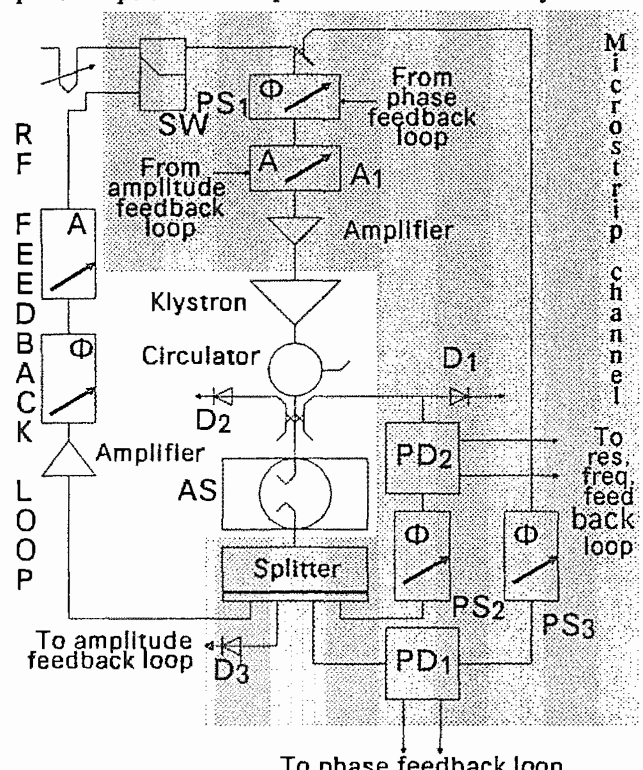

Fig.1 Outline of rf power supply of accelerating section

property of ferrite. Phase shifters are controlled by the order from the CCS with electron module. The module consists of a relay multiplexer, voltage to current converter and single channel DAC. All necessary rf parameters, such as incident, reflected waves and internal rf field, phase shifts, are measured by the CCS through optocoupled ADC. These signals are amplified and normalized by circuits of analogue feedback control systems.

Mode of power feeding.

The rf feedback loop is closed by the rf switch (SW) in the mode of power feeding into the AS. Constant phase shift and gain of rf feedback loop guarantees amplification

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PLS Beam Position Measurement and Feedback System[†]

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Abstract

A real-time orbit correction system is proposed for the stabilization of beam orbit and photon beam positions in Pohang Light Source. PLS beam position monitoring system is designed to be VMEbus compatible to fit the real-time digital orbit feedback system. A VMEbus based subsystem control computer, Mil-1553B communication network and 12 BPM/PS machine interface units constitute digital part of the feedback system. With the super-stable PLS correction magnet power supply, powerline frequency noise is almost filtered out and the dominant spectra of beam obtit fluctuations are expected to appear below $15Hz$. Using DSP board in SCC for the computation and using an appropriate compensation circuit for the phase delay by the vacuum chamber, PLS real-time orbit correction system is realizable without changing the basic structure of PLS computer control system[1].

I. Introduction

In an electron storage ring various kind of beam orbit disturbing sources exist, e.g., power line drift and ripple in magnet power supply, magnet and girder deformation by temperature changes, low frequency vibrations from mechanical vibrations of compressors, etc. When these sources are coupled with strong focusing magnets, beam orbit stability is severely deteriorated. Measurement on the spectra of beam position fluctuation shows that the dominant beam position fluctuation appear in the range $0 \sim 100Hz$[1]. In the third generation synchrotron radiation source, stability of the beam orbit is very sensitive to the noise sources. Many beamline users also require very stable photon beam source, i.e., stable within a small fraction of the beam size. Considering the photon beam sizes from Insertion Devices(ID), beam orbit should be controlled within a few μm.

Pohang Light Source(PLS) is designed as the low-emittance synchrotron radiation source[2]. The magnet lattice is $280m$ long, 12-period Triple Band Achromat(TBA) structure. Results of beam dynamics simulations show that dynamic aperture of the circulating beam is much reduced by the closed orbit distortion[3]. Without correction of the orbit distortion, even a single turn orbit may not be closed, i.e., the beam may have no dynamic aperture. In the PLS, effect of all position errors should enter within $150\mu m rms$. For these reasons, a real-time orbit correction system and local beam steering system for each ID beamlines are forseen for the Pohang Light Source.

PLS computer control system has a four-layer hierarchical structure with distributed control computers and communication networks; a host computer for the large scale computation and central database, console computers for the user interface to the control system, subsystem control computers(SCC) and machine interface units(MIU)[4]. Console computers and SCC are connected by Ethernet. SCC and MIU are connected by Mil-1553B data communication network.

PLS Beam Position Monitor(BPM) is designed as VXIbus modules to fit to the digital closed orbit correction system. All the 9 BPM detector electronics and 6 H/V correction magnet power supply(PS) control modules in a lattice period are designed to be VMEbus-compatible and are housed in a single VXIbus crate. Utilizing those VMEbus based BPM system and high performance PLS computer control system, a fully digital orbit feedback system is under development. A dedicated SCC and 12 BPM/PS MIU's constitutes the real-time closed orbit correction system.

There are some practical limitations in realizing the real-time orbit feedback system. Time delays for digital data communication and computation, and phase delay by eddy current effect of the thick aluminum vacuum chamber limit the feedback frequency range below $15Hz$. One of the biggest noise sources from power line ripples is almost filtered out in the design of PLS correction magnet power supply. Therefore, major orbit noises are expected to appear below $15Hz$ in the PLS storage ring.

II. Beam Position Monitoring System

The most important role of the PLS beam diagnostics will be the accurate and fast measurement of beam position for the stabilization of the beam orbit to meet the stringent low emittance lattice design and experimental user requirements. For this purpose, the state of the art beam position monitoring system, featuring measurement

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A Position Feedback Control System for the Test Facility of JLC

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Abstract

In order to develop an alignment system for the Japan Linear Collider(JLC), we have constructed a test facility to study the position control system with multiple degrees of freedom for massive load. Noticeable points of the test facility are as follows.

(1)Feedback fine alignment system which consists of piezoelectric actuators and laser interferometers.
(2)High-speed controller using VME modules.
(3)Level positioner driven by stepping motors.

The controller can easily be connected with other computers by using RS-232C or Ethernet, so that their states such as positions can be monitored by another computer system. This facility achieves the alignment of multi-degrees of freedom with the accuracy of the order of submicron.

I. INTRODUCTION

It is commonly recognized that a submicron alignment system will be required for the final focusing magnets of the future e^+e^- collider. As found in recent study, JLC beams at the interaction point will be as small as 1.4 nm in vertical and 230 nm in horizontal to have enough luminosity [1]. On the other hand, ground motion of the order of 100 nm is expected even at deep underground and the vibration due to the cooling water pulsation is also expected. Therefore we must keep the magnets stable against the vibration and we are considering to realize the magnet position stability by means of a feedback control, called the active alignment [2].

We have constructed a test facility for a 1.5 t magnet. The facility achieves the fine active alignment of five degrees of freedom with piezoelectric actuators. It also has the level positioners of six degrees of freedom as the coarse movers. In this report we will describe the test facility and its control system.

II. TEST FACILITY

The test facility is schematically illustrated in Fig.1 and its photograph is shown in Fig.2. The magnet support table is designed to have enough stiffness (the least natural frequency is above 100 Hz) so that it keeps its own shape unchanged under the usual vibration. The magnet support table is supported by eight piezoelectric actuators (four for vertical and four for horizontal) and the whole active alignment unit is supported by four level positioning units driven by stepping motors.

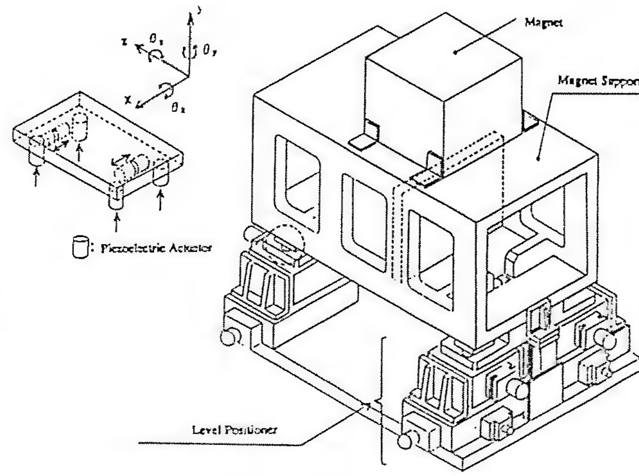

Fig.1 Schematic illustration of the test facility.

Fig.2 Photograph of the test facility.

III. CONTROL STRATEGY AND SYSTEM

Each level positioning unit has a function of three-axis positioning. Each axis has an absolute linear gauge of 1 μm resolution. With a cooperative move of the four level-

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RF Control System of the HIMAC Synchrotron

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Abstract

An RF control system of the HIMAC synchrotron has been constructed. In this control system we have adopted a digital feed back system with a digital synthesizer (DS). Combining a high power system, performance of the control system have been tested in a factory (Toshiba) with a simulator circuit of the synchrotron oscillation. Following this test, we had beam acceleration test with this control system at TARN-II in INS (institute for Nuclear Study, University of Tokyo). This paper describes the RF control system and its tested results.

Introduction

HIMAC is a heavy ion accelerator facility dedicated to the medical use, especially for the clinical treatment of tumors. The ion species required for the clinical treatment range from ^{4}He to ^{40}Ar. The required beam energy is from 100MeV/u to 800 MeV/u. This maximum energy is determined so that the silicon ions can penetrate into a human body with a depth of about 30cm. A maximum beam intensity is determined to finish one irradiation within a short time, which is 10^{11}ppp for helium beam. There is also a requirement of low intensity beam of 10^7ppp from counter experiment. The HIMAC synchrotron has been designed to satisfy these requirements. In table 1 major parameters of this synchrotron are listed. The characteristic requirements for the RF acceleration system of this synchrotron are followings.

1) Wide RF range (from 1MHz to 8MHz).
2) Wide beam intensity range between 10^7ppp and 10^{11}ppp in the synchrotron.

To control wide acceleration frequency stably with low FM noise, a digital control system with a digital synthesizer (Stanford Telecommunication, STEL-1375a) has been adopted for the HIMAC RF control system (See Fig.1) . Beam monitors of position (ΔR) and phase (Δφ), which can be used with wide beam intensity range, have been developed also. This Δφ monitor must have fast response to use for Δφ feedback loop which damp the synchrotron oscillation. We have checked the Δφ feedback loop with the developed simulator circuit in a factory. In the test with the simulator, we found that the Δφ feedback loop could damp the simulated synchrotron oscillation of frequency up to 6kHz. This result is good enough, because the maximum frequency is 4kHz in the HIMAC synchrotron. As a next step of the test, we have tried to accelerate the beam by use of the developed RF control system.

Table 1
Parameters of the HIMAC synchrotron

Beam species	He^{2+} to Ar^{18+}
Injection energy	6 MeV/u
Momentum spread of the injected beam	<±0.3%
B (injection/maximum)	.1/1.5 T
Field ramp	2 T/sec
Repetition rate	0.5 - 1.5 Hz
Maximum beam energy	800MeV/u
Beam intensity range	10^7 ppp -10^{11} ppp
Circumference	129.6 m
Transition γ	3.67
Harmonic number	4
Frequency range	1 - 8 MHz
Filling factor	0.8
Peak voltage	<11 kV (at 1MHz)
Synchrotron frequency	1 - 4 kHz

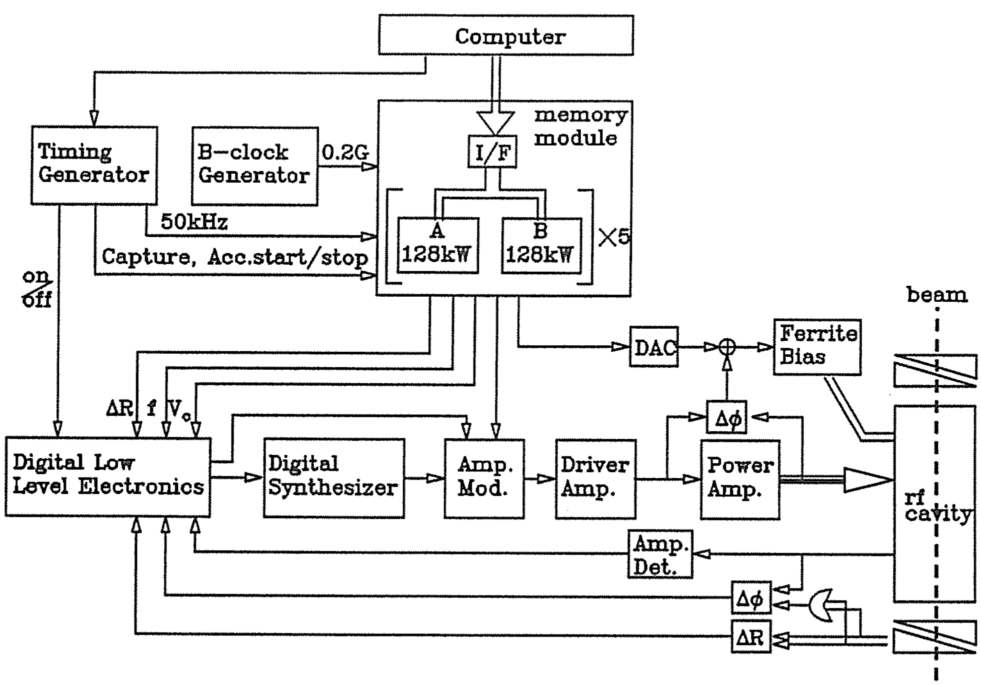

Fig.1 Block diagram of the RF system

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Development of a VME Multi-processor System for Plasma Control at the JT-60 Upgrade

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Abstract

Design and initial operation results are reported of a VME multi-processor system [1] for plasma control at a large fusion device named "the JT-60 Upgrade" utilizing three 32-bit MC88100 based RISC computers and VME components. Development of the system was stimulated by faster and more accurate computation requirements for the plasma position and current control. The RISC computers operate at 25 MHz along with two cashe memories named MC88200. We newly developed VME bus modules of up/down counter, analog-to-digital converter and clock pulse generator for measuring magnetic field and coil current and for synchronizing the processing in the three RISCs and direct digital controllers (DDCs) of magnet power supplies. We also evaluated that the speed of the data transfer between the VME bus system and the DDCs through CAMAC highways satisfies the above requirements. In the initial operation of the JT-60 upgrade, it has been proved that the VME multi-processor system well controls the plasma position and current with a sampling period of 250 μsec and a delay of 500 μsec.

1. INTRODUCTION

In the JT-60 Upgrade (JT-60U) [2] where is performed the study of magnetically confined plasma near the thermal break-even condition, the plasma current is increased up to 6 MA in the lower X-point divertor configuration. The vacuum vessel and the poloidal field coils, then, have been replaced for these improvements.

From the viewpoint of plasma equilibrium control, the vertical positional stability is one of the most important issues for the tokamak with elongated plasma. The stabilizing index n_S due to the horizontal magnetic field coil is designed to be 1.6 for the plasma with the poloidal beta β_P=0.6. The vacuum vessel, however, dose not have much effect on the stabilization, because the vessel is made of corrugated thin walls whose time constant of the field penetration is very short (τ=8 msec). Hence, it is necessary to raise the response of the feedback control system. The control cycle of the system must be less than 0.5 msec and the delay of the system must be less than about 1 msec except for the conversion time in the magnet power supplies.

Moreover, since the stored energy of plasma and electromagnetic energy of coils will increase, undesirable events such as plasma disruption may do fatal damage to the components of the vacuum vessel and the coils. More calculations, hence, are necessary to obtain the plasma parameters of positions and clearances more precisely, to produce stable plasmas and to protect the tokamak components. As shown in Table 1, the control system must, then, have such a fast data input/output capacity that it can utilize several tens of status data and several control commands. The control system must also possess such large amount of data transfer capability that it can ship up result data of a few megabytes to its supervisory computer named "discharge control computer" within a limited short time for data analysis at a shot-interval of 10 to 15 minutes.

This paper reports how we designed the control system utilizing VME components in order to satisfy the above requirements for the JT-60U plasma control. Section 2 of this paper describes the configuration of the VME plasma control system. The characteristics of the VME system including its plasma control performance are described in section 3. The final section is a summary.

Table 1 JT-60U Plasma Control Data

Item	No. of Data Channels	Data Amount (kByte)
Input Data		
Magnetic Sensor Signals	70	2,000
Coil Voltages and Currents	11	330
Control References	5	150
Calculation Data		
State Parameters of Position	5	300
Output Data		
Control Commands	5	300
Total	96	2,280

2. CONFIGURATION OF THE VME MULTI-PROCESSOR SYSTEM

As shown in Fig. 1, the JT-60 plasma control system contains two feedback loops. The major loop is for plasma heating and gas fueling control and the minor loop is for plasma position and current control which is done by using five sets of poloidal field coils. Control cycle of each loop was decided corresponding to time scale of change in its control objectives.

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Very Fast Feedback Control of Coil-Current in JT-60 Tokamak

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Abstract

A direct digital control (DDC) system is adopted for controlling thyristor converters of power supplies in the JT-60 tokamak built in 1984. Microcomputers of the DDC were 5 MHz i8086 microprocessor and programs were written by assembler language and the processing time was under 1ms. They were, however, too old in hardware and too complicated in software. New DDC system has been made in the JT-60 Upgrade (JT-60U) to control the power supplies more quickly under 0.25 and 0.5 ms of the processing time and also to write the programs used by high-level language. The new system consists of a host computer and five microcomputers with microprocessor on VMEbus system. The host computer AS3260 performs on-line processing such as setting the DDC under the discharge conditions and so on. Functions of the microcomputers with a 32-bit, 20 MHz microprocessor MC 68030, whose OS are VxWorks and programs are written by C language, are real-time processing such as taking in instructions from a ZENKEI computer and in feedback control of currents and voltages of coils every 0.25 and 0.5 ms. The system is now operating very smoothly.

I. Introduction

Control of a current, positions and configurations of plasmas in a tokamak is done by poloidal magnetic fields, and power supplies of the poloidal field coils have to be controlled very fast to suppress intrinsic instabilities of plasmas. A schematic diagram of the feedback control system is shown in Fig.1. Magnetic probes measure magnetic fluxes of plasma and a ZENKEI real-time control computer[1] performs as follows: calculating the positions of plasmas and the derivations of the reference positions, multiplying PID gains to the derivations and outputing the command of the coil-currents. Direct digital control (DDC) of JT-60 poloidal field power supply (PFPS)[2] carries out that taking in commands of the ZENKEI (I_F^{ref} in Fig.1) and giving out the delay angle cosine (Ec) to phase controllers (PHC) of thyristors. Thyristor banks have two sets of the converters which deliver the plus and minus direction currents (I_1 and I_2), respectively, and during low-current under 20% of the rating coil-current two converters supply circulating currents (I_c) to operate the thyristors smoothly.

II. DDC System

A. Functions

The DDC performs two functions in details such as on-line processing during no-discharge and real-time processing during discharge. Functions of on-line processing are as follows: (1) setting the DDC system under conditions of the discharge instructed by the ZENKEI, which are in detail instructions and checks on the discharge mode of CAMAC modules and of PHC and are diagnosis of them before the

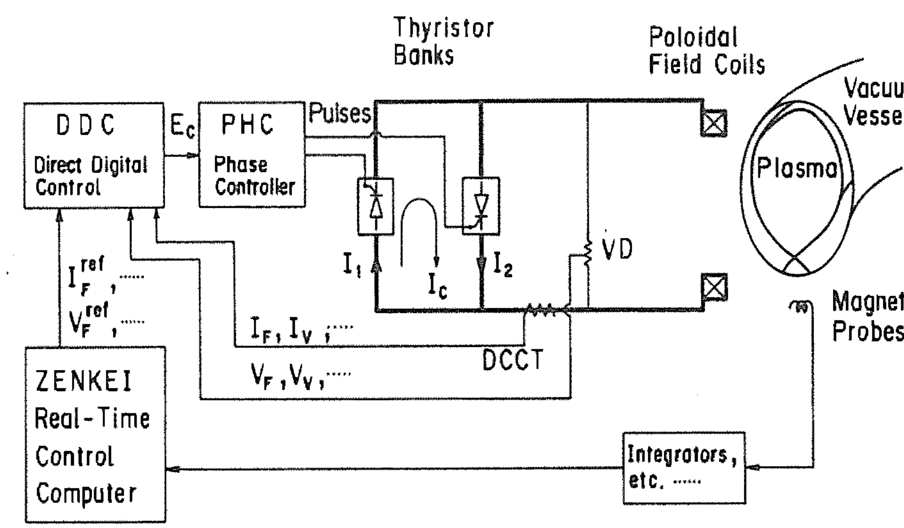

Figure 1. Schematic diagram of feedback control system of plasma position

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Workstations as Consoles for the CERN-PS Complex, setting-up the environment.

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Abstract

Within the framework of the rejuvenation project of the CERN control systems, commercial workstations have to replace existing home-designed operator consoles. RISC-based workstations with UNIX® , X-window™ and OSF/Motif™ have been introduced for the control of the PS complex. The first versions of general functionalities like synoptic display, program selection and control panels have been implemented and the first large scale application has been realized. This paper describes the different components of the workstation environment for the implementation of the applications. The focus is on the set of tools which have been used, developed or integrated, and on how we plan to make them evolve.

I. INTRODUCTION

The current control system of the PS complex is based on 16 bit computers which will be replaced because of obsolescence of the hardware and system software. A rejuvenation project is in progress for upgrading the different parts of the control system: hardware interfaces, process computers, communications and operator consoles [1] [2]. UNIX has been selected for both the console layer and the process layer.

During this first 3-year period (1989-1991), a workstation infrastructure has been set up and the basic building blocks of the programming environment have been provided. The first large scale application, the hadron injection process into the PS, has been realized for the 1991 PS complex start-up and extended during this time. This paper describes the infrastructure and the programming environment. The application programs and the user interface are both described in separate papers [3] [4]. In the context of such an evolution, the first task is to compose a base environment whose major parts are: hardware, system software, data-base management system, equipment-interface and user-interface. From experience, we were very concerned about getting as many functionalities as possible from this layer in a "safe" way: we wanted to minimize system development and be confident in the future of the environment.

The second task is to provide generic applications to support functions like console management, error handling and all direct interface with the equipment: synoptics of parts of the machine, parameter tables and control panels. This has been achieved through collaboration between the controls group and the operation group.

The third task is to integrate into the environment additional user-oriented tools for the production of specific applications and for simplification of generic tools. These tools are mostly from the commercial market and therefore it is certainly the fastest changing part.

II. BASIC ENVIRONMENT

A. Hardware infrastructure

For operation and for development, DEC™'s RISC-Ultrix™ workstations are used (about 50 in 91/92). We use common configurations with only network interface (i.e. no direct VME, CAMAC or GPIB) and local disks for virtual memory and temporary files only.

The central facilities consist of servers providing the following services: workstation system files, user files, data-base and time-sharing servers. Central time sharing servers are used mainly for resource hungry software (hardware or administration) which are transparently available on office workstations by means of the X-window network facilities.

Each local sub-network includes a regional server supporting local workstations, DSC[1]s and data. These servers are high-end workstations with SCSI disks.

One important characteristic of our current architecture is that in order to cope with man-power resources for exploitation, we opted for a very homogeneous environment. Every operation critical system is, for the time being, from a single vendor and covered by a single maintenance contract (hardware and software). This has been very efficient. However, for the sake of real vendor-independence, software portability and commercial relations, mixing vendors would be profitable, especially for tasks which are not exploitation-critical.

Another characteristic of this architecture is that our newest servers are enhanced workstation configurations instead of "mid-range" systems with high performance bus, fast dual-ported disks, etc. This is due to the increasingly faster obsolescence of the hardware and the fact that Ultrix does not

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[1]DSC are VME-based process computers with Real-Time UNIX.

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General Man-Machine Interface used in Accelerators Controls: Some Applications in CERN-PS Control Systems Rejuvenation

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Abstract

A large community is now using Workstations as Accelerators Computer Controls Interface, through the concepts of windows - menus - synoptics - icons. Some standards were established for the CERN-PS control systems rejuvenation. The Booster-to-PS transfer and injection process is now entirely operated with these tools. This application constitutes a global environment providing the users with the controls, analysis, visualization of a part of an accelerator. Individual commands, measurements, and specialized programs including complex treatments are available in a homogeneous frame. Some months of experience in current operation have shown that this model can be extended to the whole project.

I INTRODUCTION

When the decision was taken to rejuvenate the computer control system operating the CERN-PS accelerators complex [1], it was felt that users should define their needs [2]. More precisely, the end users, i.e. the operation teams had to give their views on interaction principles and tools.

The framework of this study was of course delimited by the now worldwide accepted notion of G.U.I.[1] , integrating the concepts of windows, pull-down menus, pop-up menus, icons and objects selection, all these being driven by a powerful multitasking system [3]. Taking into account the dimension of the process - the PS complex includes 10 accelerators - a prototype had to be constructed in order to evaluate the new human interface proposed.

The hadron beam transfer line from the 1 GeV Booster synchrotron and the related CPS injection process were selected as guinea pigs. The principles and applications are described below.

II PROCESS STRUCTURING

In a very large process to be controlled from a centralized point, the first task consists in defining a structure allowing each member of an operating team to work in a quasi independent and secure way. These principles were already successfully introduced in the present control system [4] and are kept here. Moreover, the PS accelerators complex pulse-to-pulse modulation (PPM) working mode [5] imposes the notion of virtual machine: a parallel adjustment of concurrent beam types in the same accelerator is possible.

From the above the concept of an *Application* emerged: the whole lot of application programs needed to operate a logical part of an accelerator in an autonomous manner. We are talking here of the "CPS 1 GeV Injection Application" given as an example.

An Application includes:

- the complete access to the control/acquisition of the parameters set composing the sub process
- the controls of the dedicated measurement devices and associated presentation programs
- the temporary specialization of some general measurement devices (dedicated initialization of parameters)
- access to particular application programs developed for the specific sub process.

The term Application will be used in what follows to designate the working environment defined above.

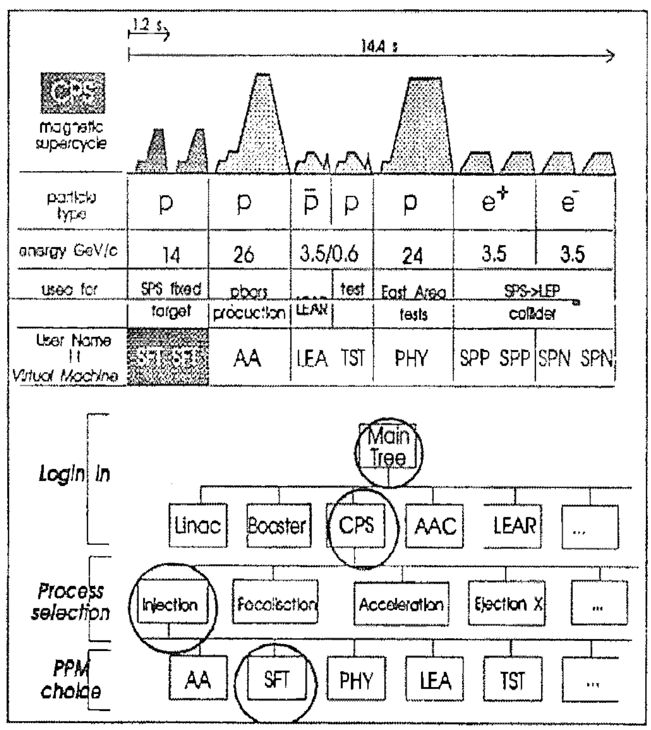

figure 1: a CPS supercycle showing the succession of beam types and selection structure scheme. Illustrated: The 1 GeV Injection Application addresses to the CPS parameters valid for the beam sent to the SPS accelerator.

[1] Graphical User Interface

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The Replacement of Touch-Terminal Consoles of the CERN Antiproton Accumulator Complex (AAC) by Office PC's As Well As X-Windows Based Workstations

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Abstract

With aging hardware and expensive maintenance and replacement possibilities, it was decided to upgrade the AAC touch terminal consoles with modern hardware. With significant amount of operational application software developed with touch terminals over 10 years, the philosophy adopted was to attempt a total emulation of these console functions of touch actions, graphics display as well as simple keyboard terminal entry onto the front-end computer controlling the AAC. The PC based emulation by mouse and multiple windows under MS-DOS and later, under the Windows 3 environment was realized relatively quickly; the next stage was therefore to do the same on the Unix platform using software based on X-windows. The communications channel was established using the TCP/IP socket library. This paper reviews this work up to the operational implementation for routine control room usage for both these solutions.

INTRODUCTION

The CERN Antiproton Accumulator Complex (AAC) is composed of two circular, concentric ring accelerators and an antiproton production area (see Fig. 1). The inner ring, the Antiproton Accumulator (AA) was commissioned in 1980 while the outer, Collector ring (AC) was brought into operation in 1987 to permit an order of magnitude increase in the antiproton flux. The AA was conceived initially as an experiment and was built and commissioned in record time while the CERN PS Complex of accelerators was undergoing major changes from rudimentary to modern computer controls. For reasons of time and financial expediency, it was considered necessary to have cheap operator interaction means available for the AA commissioning, with simple to use interpreter (Nodal) based facilities. The Touch Terminals [1, 2], developed and used for the CERN-SPS control room were ideally suited for this role [3]. The controls system provided the necessary facilities to connect the Touch Terminals to the equipment. The AA controls system and its extension and upgrade in 1986 has been amply described elsewhere [4, 5].

THE PRESENT TOUCH TERMINALS

The Touch Terminal (TT) is a specially configured mini-CAMAC crate with a microprocessor and special modules to drive a touch button screen, a graphics and character display screen and is connected to the front-end computer which controls the equipment via CAMAC Serial highways. Communication between the computer and the TT is by means of the standard current loop serial interface. The microprocessor controller in the TT is programmed to be transparent to the front-end computer terminal driver. However, it also detects or inserts certain "escape sequences" enabling the simple touch button functions like LEGEND, BUTTON etc. and graphic monitor functions like VECT, TEXT and so forth. Hence, the TT simply appears as a standard terminal to the controls computer but provides powerful interaction facilities with equipment. For the antiproton improvement programme at CERN and in preparation for the construction/commissioning of the AC ring in 1986-87, the TT's were upgraded to a Motorola 68000 based microprocessor, permitting colour alphanumeric and graphic facilities as well as higher terminal speeds. This, together with a faster front-end computer, has permitted up to five operational TT's for the AAC since 1986.

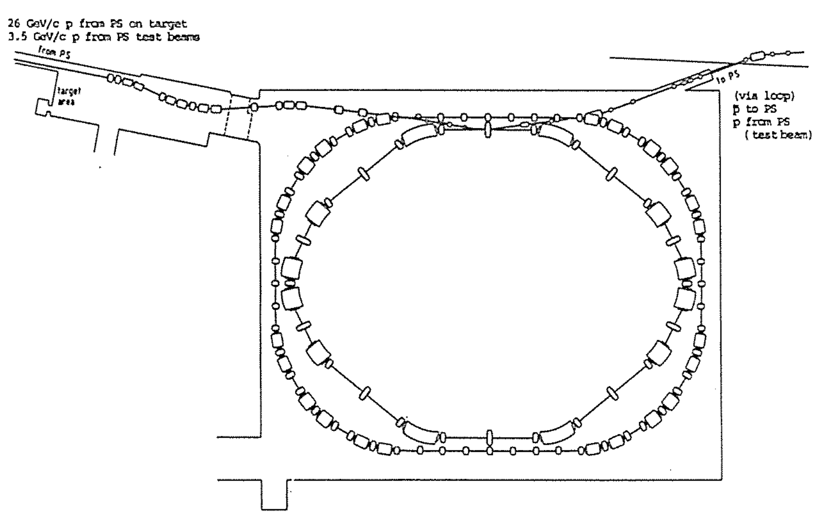

Fig. 1. General layout (magnetic elements only) of the Antiproton Accumulator Complex (AAC): outer ring - Antiproton Collector (AC), inner ring - Antiproton Accumulator (AA).

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The Elettra Man-Machine Interface

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Abstract

ELETTRA is a third generation Synchrotron Light Source under construction in Trieste (Italy), with beam energies between 1.5 and 2 GeV. Two networks connect three layers of computers in a fully distributed architecture. An ergonomic and unified approach in the realization of the human interface for the ELETTRA storage ring has led to the adoption of artificial reality criteria for the definition of the system synoptic representation and user interaction. Users can navigate inside a graphic database of the whole system and interactively edit specific virtual control panels to operate on the controlled equipment. UNIX workstations with extended graphic capabilities as operator consoles are used in the implementation of the PSI (Programmable Synoptic Interface), that was developed on top of X11 and PHIGS standards.

I. Introduction

We may think of an ideal man-machine interface (MMI) as a tool which allows users to interactively specify their preferred means of interaction with the devices controlled, using graphic programming techniques to compose predefined objects that support the exchange of numeric, string or graphic information. A definition of new specific objects is also possible using an editor with similar properties.

Commercial interfaces ado not generally combine these two requirements without the introduction of a considerable amount of new concepts and notions. Today we can profit by the wide diffusion of some advanced graphic user interfaces (GUIs), based on a well defined set of composable objects, or *widgets*, that have certainly increased the knowledge of interface principles and interaction paradigms among users. A similar awareness at the lower level, where graphic primitives and basic interaction techniques should be structured together to form an object, is at present unthinkable. As a matter of fact, a global definition of the semantic and syntax of graphic human-computer interaction still suffers from a lack of standardization of the relative graphic and dialogue lexicon, which is a young field of active research. Interactive widgets composers are indeed filling up the market, while a similar approach for the definition of widgets is practically abandoned.

II. Design Goals

In our project of a MMI for the Elettra storage ring the aim of obtaining a well balanced integration between new powerful features available on modern hardware and software platforms, and a comprehensive exploitment of innovative methodologies concerning human-machine interfaces, has led to a continuous revision of the design and implementation phases, together with a considerable effort in testing prototypes with real users.

The usual top-down design approach which uniquely guarantees consistency in terms of colour coding, menus and dialogues layout, warning messages and overall behaviour of the user interface is left at the end, when all possible user interactions are already defined.

Two main lines have been followed in the design of Ψ (Programmable Synoptic Interface), in order to keep the amount of new concepts required for its operation to a minimum;

- to hide all the details concerning the specific structure of our control system from the users. A complete transparency of operative system, programming language, graphic and communication libraries is therefore essential.

- to take full advantage of all the notions users are already familiar with: the local operations of the devices, the planimetrical layout of the machine, the commonly used desktop metaphor as a computer interface.

III. Conceptual Organization

A possible solution to these demands was to adopt typical artificial reality criteria for the design of our interface. A planimetric representation of the whole system, where all the items controlled are shown with their real shape and position, was recognized as the users' most familiar environment. The equipment displayed inside the environment is associated to virtual control panels which allow users to operate the graphic representation of a large set of devices like switches, knobs, sliders, digital and analogue indicators, whose behaviour is equivalent to that of the same instrumental devices. A set of well defined interaction paradigms regulates the navigation inside the environment, the modification of the scale and visibility of the layers into which the graphic information is structured, the selection of devices and the activation of the relative control panels.

Let us now distinguish between the principal elements that compose our artificial world:

-an *environment*, i.e. a synoptic representation of the whole system;

- a set of *objects*, i.e. the devices controlled;

- a collection of *virtual control panels*, i.e. the logical grouping of controls associated to one or more devices;

- a set of *interaction paradigms* between the user, the environment and the objects.

The environment consists of a complete graphic database of the whole system, no longer restricted to fixed size views of selected parts of the plant. If we define the graphic database at system level, freeing the user from the synoptic drafting

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Exploiting the X-Window Environment to Expand the Number, Reach, and Usefulness of Fermilab[1] Accelerator Control Consoles

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Abstract

The Fermilab accelerator operator workstation of choice is now the Digital VAXstation running VMS and X-Window software. This new platform provides an easy to learn programming environment while support routines are expanding in number and power. The X-Window environment is exploited to provide remote consoles to users across long haul networks and to support multiple consoles on a single workstation. The integration of imaging systems, local datalogging, commercial and Physics community's software, and development facilities on the operator workstation adds functionality to the system. The locally engineered knob/pointer/keyboard interface solves the multiple keyboard and mouse problems of a multi-screen console. This paper will address these issues of Fermilab's accelerator operator workstations.

I. CONSOLE HARDWARE

The accelerator console is built around a VAXstation color workstation running VMS and X-Window software. The VAXstation 3200, VAXstation 3520, VAXstation 3100/30, 3100/38, 3100/76 and MicroVAX II are in use as workstation processors. The displays have either 1280 by 1024 or 1024 by 768 resolution with 8 bits per pixel.

Network communication to other accelerator processors is via accelerator-control network (ACNET) software using either a locally designed token-ring card or an Ethernet to token-ring bridge. Communication for system management, accelerator clock, and other purposes is via DECNET and TCP/IP over Ethernet.

A single-screen console provides full functionality, but some control room users require multiple displays. X-terminals using TCP/IP and Ethernet provide these additional screens. The NCD-17c is the preferred X-terminal for this control system.

II. EXPANDING THE NUMBERS

The number of consoles connected to the Fermilab accelerators is rapidly growing. Where 20 consoles served Fermilab for 10 years and budgets were prepared for 50 new consoles, the demands for VAXstation consoles are exceeding that estimate. 33 VAXstation consoles are active with 24 additional VAXstations scheduled to be purchased by Spring, 1992.

The increased numbers are due to a variety of factors. Many requests for accelerator consoles were denied over the years due to high cost and difficulty of installation. The new console with symbolic debugging support is a productive rapid cycle development machine. Users want convenient access to accelerator information, often in their office.

However, greater numbers of consoles present larger demands on central services and front end data acquisition nodes requiring consequent upgrades in those areas and the introduction of application program time-outs and other measures to balance high accessibility with overall throughput.

As new models of VAXstations are announced and released, we tend to purchase machines with better performance and value. It is clear that a console supporting a development cycle has an excess of cpu cycles and network bandwith. Utilizing that excess power is possible by supporting multiple consoles on a single VAXstation.

A. X-server consoles

The software architecture of a console is relatively simple. A large shared memory and shared library, several manager tasks and user applications make up a console. Splitting the shared memory region into a global area and multiple console specific area provides the ability to run additional alphanumeric, graphic, and utility managers, and sets of user applications. An X-server console is obtained at the cost of an X-terminal for the window displays. Twenty X-server consoles are in regular use primarily in the offices of programmers and accelerator operations specialists.

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[1] Operated by Universities Research Association for the Department of Energy

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A Virtual Control Panel Configuration Tool for the X-Window System

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Abstract

Computer Graphics Workstations are becoming increasingly popular for use as virtual process control and read back panels. The workstation's CRT, keyboard, and pointing device are used in concert to produce a display that is in essence a control panel, even if actual switches and gauges are not present. The code behind these displays is most often specific to one display and not reusable for any other display. Recently, programs have been written allowing many of these virtual control panel displays to be configured without writing additional code. This approach allows the initial programming effort to be reapplied to many different display instances with minimal effort. These programs often incorporate many of the features of a graphics editor, allowing a pictorial model of the process under control to be incorporated into the control panel. We have just finished writing a second generation software system of this type for use with the X-window system and the Experimental Physics and Industrial Control System (EPICS). This paper describes the primary features of our software, the framework of our design, and our observations after initial installation.

BACKGROUND

The EPICS[1] control system consists of an input-output controller subsystem that communicates via a software bus with many general purpose or application specific control system components. The input-output system provides the time critical and hardware specific portions of the control system. The software bus or "channel access" provides standardized communication between control system components over a local area network. EPICS has the following general purpose components: an alarm manager, an archive subsystem, a timing subsystem, and the operator interface which this paper describes.

A first generation operator interface, developed for the telescope control system, has been deployed at the Argonne National Laboratory and elsewhere by the Los Alamos National Laboratory[2]. This operator interface was next ported for use on the EPICS control system and used on the Ground Test Accelerator and related test stands at LANL. This first generation operator interface proved the effectiveness of the virtual control panel technique for reducing the applications programming effort[2].

This paper describes the design and implementation of a second generation operator interface. We wanted to replace the obsolete graphics platform on which the first generation was built with the open X Window System standard. Other goals were faster display startup and update rates, and more effective configuration tools[3]. We also wanted to build a proper foundation on which we could build future extensions and enhancements, while spending less of our time on software maintenance.

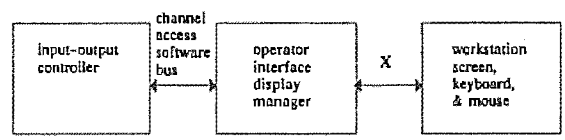
*Work supported and funded under the Department of Defense, US Army Strategic Defense Command, under the auspices of the Department of Energy.

FEATURES

The second generation operator interface or OPI consists of an editor which is used to create and configure virtual control panels and a display manager which activates them. A display

file containing the virtual control panel description is the only form of communication between the two programs.

Once activated, displays can be used to monitor and control



process variables. The display manager accomplishes this by responding to external events and updating the screen. External events include keyboard input, mouse input, or process variable state changes.

Operator interface displays are configured with a graphics editor capable of manipulating the normal complement of graphics object primitives such as rectangles, lines, ovals, arcs, and text. In addition to these primitives, the editor can also configure a full complement of process variable control and read back components such as indicators, meters, buttons, and menus. Once created, one or more graphics objects can be selected for cutting, copying, pasting, moving, or scaling. These techniques can be used to move groups of objects between several operator interface displays under edit on the same workstation. The editor also supports features for productive alignment and even distribution of object groups. The editor saves a finite list of all previous operations so that they may be individually undone at the operator's discretion.

A graphics form for modifying attributes is provided for each type of object which can be created by the editor. The forms have entries for every operator modifiable attribute even if some attribute modifications, such coordinate translations, can be carried out more efficiently with the mouse. These graphics forms or property sheets provide a simple and consistent method for entering the more complex configuration required by process control and read back components such as plots or indicators. For example, a bar indicator might require entry of a process variable name, labeling option, direction of increase, and a color modifier (the color could be static or based on an alarm condition).

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X-Window for Process Control in a Mixed Hardware Environment

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Abstract

X-Window is a common standard for display purposes on the current workstations. The possibility to create more than one window on a single screen enables the operators to gain more information about the process. Multiple windows from different control systems using mixed hardware is one of the problems this paper will describe. The experience shows that X-Window is a standard per definition, but not in any case. But it is an excellent tool to separate data-acquisition and display from each other over long distances using different types of hardware and software for communications and display. Our experience with X-Window displays for the cryogenic control system and the vacuum control system at HERA on DEC and SUN hardware will be described.

I. Cryogenic Controls

A. Components

The cryogenic control system for the HERA collider -which has a circumference of 6.3 km- is based on a commercial, distributed control system called D/3. The backbone of the system is a redundant communication link using HDLC protocol and a token passing algorithm(Fig. 1). Display and control functionality a separated from each other in the individual display- (DCM) and process control computers (PCM). The cryogenic processes, as there are: compressors, coldboxes, helium distribution in the HERA tunnel to the 422 superconducting dipole- and 224 quadrupole magnets, low temperature measurement, superconducting cavity control, supervisory control for the ZEUS solenoid, controls for the magnet test hall etc. are controlled by means of the PCMs. More than 3000 analog and 3100 digital signals are scanned,archived and calculated in control loops and logic devices. The scantime for the individual points is defined to be between 0.25 [sec] for fast control loops and 3 [sec] for temperature read-out of the HERA magnets. All points are checked for over and underrange, and high and low limits. Alarms are send to various printers throughout the system according to the alarm destination index (ADI). The printers can be host based or connected to terminal servers.

B. Access

All process points can be accessed from any PCM and DCM in the whole system. This way no 'special' consoles exist in the system for process control. There are some consoles that have additional/other functionalities like annunciator panels with function keys and X-Window displays with or without the full access to the process. This (X-)extension to the existing system is very useful since the architecture of the D/3 system does only foresee consoles directly connected to one of the DCMs. X-Displays of the cryogenic control system are now running in various places at DESY: In the main control room where the D/3 link is not jet installed, and where ever it is useful for the

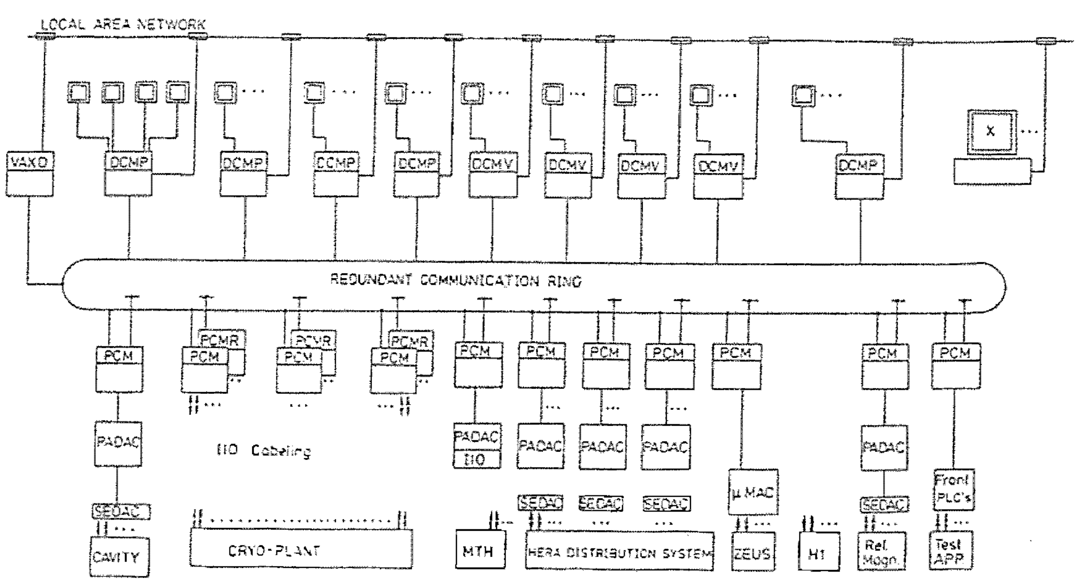

Figure 1. The Cryogenic Control System

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An Open Software System Based on X Windows for Process Control and Equipment Monitoring

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Abstract

The construction and application of a configurable open software system for process control and equipment monitoring can speed up and simplify the development and maintenance of equipment specific software as compared to individual solutions. The present paper reports the status of such an approach for the distributed control systems of SPS and LEP beam transfer components, based on X Windows and the OSF/Motif tool kit and applying data modeling and software engineering methods.

I. INTRODUCTION AND MOTIVATION

A. Equipment

Equipment for SPS and LEP beam transfer at CERN comprises systems like the SPS injections, extractions, targets, dumps, and collimators, and the LEP injections and separators. In total some 80 distinct systems spread over both accelerators and the fixed-target areas have to be controlled. At present, new control systems for the LEP beam dump and the LEP Pretzel separators are being prepared.

Although the functionality and the composition varies considerably between the different systems, all can essentially be characterized as 'slow controls': Reaction times as seen from the main control room are of the order of seconds; any fast responses, e.g. for beam dumping, are supported by special hardware. The amount of data exchanged between the main control room and the devices is small.

B. Equipment Software

However, comprehensive equipment specific software has to be provided to achieve the desired level of abstraction towards the main control room, to allow monitoring of the equipment performance, and to dispose of efficient tools for local and remote fault-finding to help keeping down-times low, in particular in view of the volume and the distances involved.

For this sake a lot of code has been written up to now, especially with the large-scale use of distributed processing. Due to the limited manpower there is a strong risk of bottlenecks in the treatment of requests for modifications or extensions which might arise from an evolving environment or an increased sophistication of use.

C. Tool Kit Approach

This experience has encouraged us to try a different approach by replacing our equipment specific programs by a general software system or tool kit which receives its individual functionality through a formal description of the equipment and the desired function in tables. If this idea is pursued rigorously almost full separation between code and data can be obtained, leaving only pieces of specific code behind which are uneconomic to parametrize.

As possible advantages we see, besides others, a more uniform appearance of the equipment, a more transparent specification phase with improved communication between hardware and software specialists, leaving less room for misunderstandings, and a shorter reaction time for developments and modifications.

Before starting the development we made some investigations in the commercial sector. At that time we came to the conclusion that a separate development could well be justified in view of the potential problems encountered when embedding and maintaining a commercial process control system in a given and evolving environment, disregarding any price argument. With time passing by, we might however come to a different finding.

To make our task more feasible we did not attempt to write a full package from scratch but rather tried to re-use a maximum of existing packages, tools, and mechanisms, combining them into the desired product.

One of the key goals was to arrive at a portable, thus platform independent, and evolvable software system which should be easy to adapt to changing environments or increasing needs. This becomes particularly attractive in combination with the X Windows system and the OSF/Motif tool kit since they allow to perform input or visualize complex results on a large variety of media without much adaptation work.

In the following we will first give an overview of the tool kit concept and describe its key ingredients, then the chosen implementation. Afterwards, we will present results obtained in a prototype application, followed by a status report and an outlook.

II. TOOL KIT CONCEPT

The layout of the tool kit and the way the user interacts with it is sketched in figure 1.

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Porting Linac Application Programs to a Windowing Environment

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Abstract

We report our experience in porting Linac application programs written for Camac controlled hardware consoles to an X-Windows/Motif based workstation environment. Application programs acquire their parameter values from a front end computer (FEC), controlling the acceleration process, via a local area network. The timing for data acquisition and control is determined by the particle source timing.

Two server programs on the FEC for repetitive acquisition and command-response mode will be described.

The application programs on the workstations access a common parameter access server who establishes the necessary connection to the parameters on the FEC. It displays the parameter's current values and allows control through Motif widgets.

An interactive synoptics editor and its corresponding driver program allow easy generation of synoptics displays and interaction through command panels.

I. THE EXISTING SYSTEM.

The control system for our Proton Linac has been designed and implemented in the mid seventies. The system is based on a single PDP-11 minicomputer running the RSX-11 operating system. Because of the memory sizes available at that time all system software and a major part of the application programs has been written in Macro-11.

The software system consists of 3 logical parts:

- The equipment driving software: all equipment is interfaced through serial Camac. This software part contains a "central request processor" collecting all requests for Camac access and sending out Camac command in synchronism with the particle source timing.
- Software managing the operator consoles the consoles are interfaced through parallel Camac
- The application programs.

For historical reasons the Linac control system is the only accelerator control system in our division that uses PDP-11 computers. All other machines are controlled with Norsk Data equipment. The consequence of this is the impossibility to access the Linac control system from the general purpose operator consoles in the main control room (MCR), since the computer networks of the two types of systems are incompatible. The first goal for this project was therefore to give access to Linac parameters through the new workstation operator consoles.

II. THE NEW SYSTEM

The old PS control system is in a process of rejuvenation [1] according to the new common architecture for CERN accelerator [3]. In this global plan a special plan was defined for our Proton Linac. This was especially needed by the impossibility to maintain any more the equipment of the Linac consoles. It was also an opportunity to gain experience in windowing environment and in porting old style application into this environment. To achieve this halfway solution, we decided to connect the PDP11 front end computer to Ethernet network and to use Decnet communication package between these front end and the Ultrix workstation. This network software was the only one supported by the manufacturer DEC on the RSX11-M operating system of the PDP11. We therefore needed to write Decnet server for PDP11 to allow remote access from the workstation to the equipment.

III. NEW SOFTWARE WRITTEN FOR THE PDP-11

Because the Proton Linac is almost permanently running during the whole year, only a gradual switchover to the new system seems possible. We therefore decided to rewrite the major application programs under X-Windows/Motif for the workstations and leave the change of the parameter access processes to the DSC for a later date. In order to be able to operate the Linac from a workstation we identified the following software as absolutely indispensable:

- access to any single parameter for acquisition and control;
- synoptics;
- logs;
- several application programs, especially beam diagnostics.

Leaving the old consoles in the Linac control room in place and the old programs accessible, it was possible to install the new application software without interference in the operation of the accelerator. To make the parameter-access-part of the PDP-11 system available to the external world, two "server programs" on the PDP-11 had to be developed. The first one (VXS) operates in command-response mode, waiting for a command sent to it over the network. This command is translated into calls to the hardware driving software and submitted. The response is put back into a network packet and sent back to the requester. The command-response server accepts commands to acquire equipment data and status, to control equipment and to get database information like min/max values, convertion factors and the like.

The second server (SNS) gets a collection of equipment parameter names and performs continuous acquisition on these parameters. The acquisition values are periodically sent back to the requesting client program. The timing for the acquisition is given by the proton source timing which pulses at a rate of 1 Hertz.

The only network software available under RSX11-M is an incomplete implementation of DecNet, which does not allow to open more than 1 logical link to another task. Real server processes are therefore impossible. The only way to allow several tasks access to Linac parameters is to duplicate the "servers".

In addition to the "servers" described above (SNS,VXS), which are the most important ones, a GPIB server, a CAMAC

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A New Workstation Based Man/Machine Interface System for the JT-60 Upgrade

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Abstract

Development of a new man/machine interface system was stimulated by the requirements of making the JT-60 operator interface more "friendly" on the basis of the past five-year operational experience. Eleven Sun/3 workstations and their supervisory mini-computer HIDIC V90/45 are connected through the standard network; Ethernet. The network is also connected to the existing "ZENKEI" mini-computer system through the shared memory on the HIDIC V90/45 mini-computer. Improved software, such as automatic setting of the discharge conditions, consistency check among the related parameters and easy operation for discharge result data display, offered the "user-friendly" environments. This new man/machine interface system leads to the efficient operation of the JT-60.

I. INTRODUCTION

The former JT-60 supervisory control system named "ZENKEI" consists of seven mini-computers and a CAMAC system for controlling tokamak machine operating conditions, discharge sequences and plasma equilibrium control.[1] Although been adequate the performance of "ZENKEI" has heavily worked, its limitations such as memory size, calculation speed, word length reached its limitation due to the option of the lower X-point operation and pellet injection system.

The new "ZENKEI" has to provide the long pulse operation (up to 15 sec), high speed plasma position feedback control (250μsec) and more user-friendly man/machine interface. [2],[3]

To satisfy the above requirements, we modified the plasma feedback control system of the two mini-computer system to that of a VME system. The man/machine interface system was changed from that of simple terminals to workstations. These workstations provide UNIX operating system with features of a multi-window system, network file system and many application tools for data handling and graphic interfaces. The improvements of the man/machine interface system have been made for the setting the discharge condition parameters, operation of the discharge and displaying of the discharge result data waveforms on the basis of the "friendly".

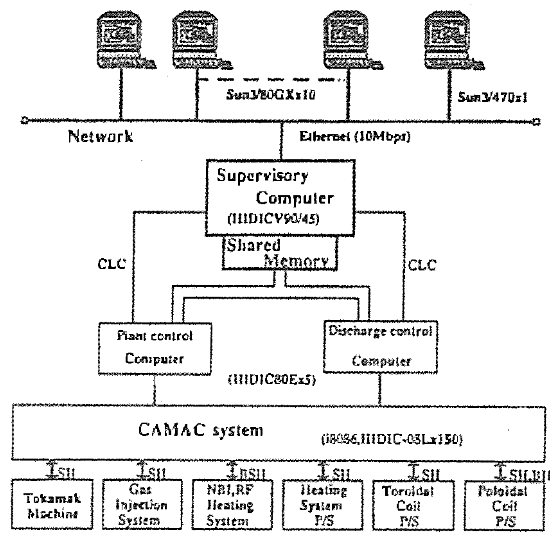

Fig.1 Man/machine System configuration in ZENKEI

II. SYSTEM CONFIGURATION

A. System Overview

The ZENKEI was composed of five mini-computers for discharge control and monitoring of plant operations. The CAMAC modules are used for data acquisition and control. Two mini-computers for high speed plasma position and shape control. The 14 CRT displays with keyboard and push-button switches had been prepared as the operator interface. This system had contained the following major functions;

- set discharge condition parameters,
- execute a discharge sequence,
- monitor the subsystem's operating status, and
- display the discharge result data.

The modification of many discharge condition parameters within a short period of time placed a big burden to the operator. Furthermore, the operator had to move back and forth from a certain console with a certain function to another with another. In addition, only a small memory had remained as a result of many modifications.

In order to improve the man/machine interface, computer hardware had to be replaced. The new man/machine interface

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A Flexible Graphic Display System for Accelerator Control

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Abstract

A flexible graphic display system for controlling the KEK Photon Factory storage ring has been developed.

A VME computer locally controls the graphic display system and communicates with the host control computer through a RS-232C link. Graphic pictures are prepared in the local system by an interactive operation using either a tablet or a keyboard. The host control computer is free from any load due to graphics processing. In an on-line operation, pictures are displayed and modified by simple command strings from the host computer.

A "picture stack" method has been developed for this graphics system. The latest demanded picture always has top priority to be presented on each display monitor. Previous pictures are saved in a stack and can reappear when the current picture has been freed.

1. Introduction

Since colorful graphic displays can provide us with much useful information, even at a glance, they have become one of the indispensable tools needed for modern control systems. However, it often requires many man-hours to prepare a graphic display system, since graphics software is usually complicated and difficult to use. Furthermore, such graphics processing puts a heavy load upon control computers.

We have developed a flexible graphics display system (FGS) for controlling the Photon Factory storage ring. FGS has the following features:

- Host control computers are free from graphics processing load.
- Graphics are easily prepared without programming.
- Co-ordinate-free location method is possible.
- Any picture can be presented on any display monitor.
- Several pictures are kept in a stack manner for each monitor.
- Co-operative work with FTS (flexible touch screen system [1]) is possible.

2. System Overview

A schematic of the FGS architecture is shown in fig. 1. The control system uses four minicomputers (FACOM S-3500 from Fujitsu) linked to each other by a token ring-type network [2]. The FGS control task (FGSCT) resides in one of the control computers. Many application tasks for control are distributed over four control computers. The application task sends a request to display a necessary graphic picture to FGSCT by DSM (Data Stream Manager, inter-task communication utility based on network [2]). FGSCT manages those requests from various application tasks. When it accepts a display request, it establishes a connection path between the application task and a proper display monitor. Hereafter, the application task is able to make modifications on a displayed picture. The connection path is valid until the application task frees this picture.

An intelligent graphic display station (DP-1000 from Digital) receives commands from FGSCT and draws pictures. One DP-1000 can handle three independent display monitors. The link between S-3500 and DP-1000 is RS-232C.

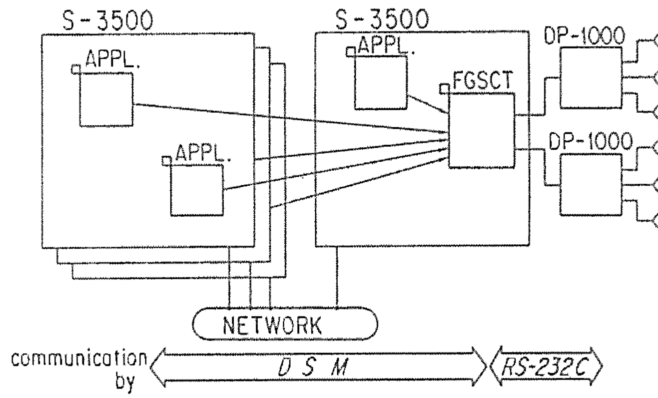

Fig. 1. Schematic of the FGS architecture.
APPL.: Application Task
FGSCT: FGS Control Task
DSM: Data Stream Manager (Inter-task communication based on token ring network)

3. Function of FGS

A basic concept of FGS is that intelligent graphic display stations can present pictures by commands from control computers. Since the display stations perform all of the graphic processes, the control computers have only to send short command strings. Graphic pictures are prepared beforehand by the display station in a stand-alone manner.

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Human-Machine Interface Software Package

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Abstract

The Man-Machine Interface software Package(MMISP) is designed to configure the console software of PLS 60Mev LINAC control system [1]. The control system of PLS 60Mev LINAC is a distributed control system which includes the main computer (Intel 310) four local station, and two sets of industrial level console computer. The MMISP provides the operator with the display page editor, various I/O configuration such as digital signals In/Out, analog signal In/Out, waveform TV graphic display, and interactive with operator through graphic picture display, voice explanation, and touch panel. This paper describes its function and application.

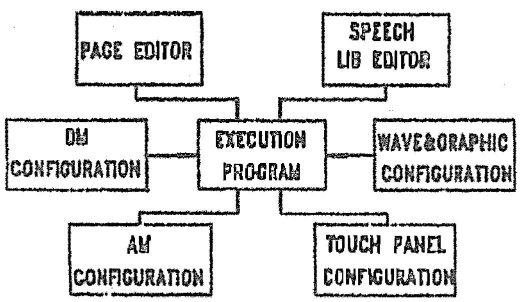

Fig.1 The Structure Diagram of MMISP

I. Introduction

Recently, the control level has grown up so fast by VLSI technology development. There are many kind of Workstion developed for interactive tool between operator and computer. Of course it has more powerful function but is also is expensive and can't connect a small system easily. We introduce a interactive software which is highly cost-effective, compact, and emphasizing easy operation based on the PC.

II. System Structure

The MMISP shown as Fig.1 includes seven subroutines which are the Page Editor, the Speech library Editor, the Digital Monitor(DM) Configuration. the Analog Monitor(AM) Configuration and the Execution Program.

A. Page Editor

The page editor is used to edit the display picture and to create the drawing library. Its main function is follows:

* Drawing the line, circle, block line by cursor or up/down, left/right key
* 16 color could be selected
* The Picture can be moved, copied and loaded in hard disk as subpicture page

B. I/O Configuration

1. The DM configuration is used to create the display message of digital signals for the user's page, and the message will be saved in the page setting file. It has 5 kinds of digital display mode, which are the painting given area, the character string display, the drawing element display, the turn to the given page and the speaking something.

2. The AM configuration is applied to generate the display message of analog signals for the user's page, and the message will also be saved in the page setting file. It has six kinds of analog display modes, which are the digital display that the digit number can be selected from 1 to 7, the rectangle or other shape image display, the pointer meter display, and the turn to given page or the speaking something if the analog signal is overvalue.

3. The Wave & Graph Configuration is applied to create the display message of signal waveform, such as pulse voltage wave, or TV image for the user's page, and the message, such as the coordinate and display color etc., will be saved in the page setting file.

4. The Touch Panel Configuration is used to define the function of touch area, and to save these definitions in the page setting file. It has ten functions which are the recovering original color of given area, the changing color of given area, the input and display for a character string or data, the making a character string or data available or

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Correlation Plot Facility in the SLC Control System*

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Abstract

The Correlation Plot facility is a powerful interactive tool for data acquisition and analysis throughout the SLC. This generalized interface allows the user to perform a range of operations or machine physics experiments without the need for any specialized analysis software.

The user may step one or more independent parameters, such as magnet or feedback setpoints, while measuring or calculating up to 160 other parameters. Measured variables include all analog signals available to the control system, as well as calculated parameters such as beam size, luminosity, or emittance. Various fitting algorithms and display options are provided.

A software-callable interface has been provided so that a host of applications can call this package for analysis and display. Such applications regularly phase klystrons, measure emittance and dispersion, minimize beam size, and maintain beam collisions at the interaction point.

INTRODUCTION

Early in the development of the SLC, a generalized tool was written to acquire online data, and perform analysis and display functions across a wide range of information for many users. Rather than develop similar pieces of code for each combination of data, the Correlation Plot facility was designed generically to handle all of the data types available, and be extensible to other types that might evolve.

Due to the initial success of this implementation, a software-callable interface was added, so that other packages could make use of these fitting, plotting, and display facilities. This approach avoided redundant developments and provides a more consistent user interface for other parts of the control system.

ORGANIZATION

The main elements of the Correlation Plot facility are:

- A general control package which can step through setpoints of magnets, klystrons, feedback loops, timing parameters, and other device points of interest.
- A general data acquisition facility that can acquire data from a variety of sources, including high level parameters derived from analysis of klystron fast time plots and wire scans.
- A range of curve fitting algorithms, including average, linear, polynomial, sinusoidal, Gaussian, and specialized beam deflection curves.
- A general plotting package to display the acquired and fitted data. The sampled data may be plotted against the step variable, any of the sampled quantities, or the step number.
- A generic optimization feature allowing users to create a correlation plot to vary a step variable; obtain sampled data for each point, fit a parabola to the data, and implement the value of the step variable that results in the fitted minimum.

*Work supported by Department of Energy contract DE-AC03-76SF00515.

INTERFACES

Touch Panel

The Correlation Plot facility is an integral part of the SLC Control Program SCP [4]. The primary user interface utilizes a touch panel or cursor keys, although a mouse and trackball have been added as part of a newer X-window SCP. The main panel provides buttons for specifying the step and sample variables, selecting the range of the step variable, and setting other acquisition parameters. A generalized input parser interprets the input in a context-sensitive manner, where the meaning of each token depends on the valid tokens already accumulated. At any point, a list of the valid responses may be requested as a guide to the user.

From the touch panel or keyboard, the user may initiate data acquisition, terminate acquisition, or temporarily pause during an acquisition sequence. After data is acquired, display panels allow selection of fit and plot options. The user may request displayed or printed plots, as well as tabular formats. It is possible to specifically include or exclude selected data points, and have the facility recalculate the fit parameters.

An auxiliary output panel allows extended use of the system. Thus users may save data to disk files in various formats for offline analysis. Alternatively, users can reload previously stored command strings, or variables and data files, for further online analysis and display.

Callable Routines

All of the actions that are accessible via the operator interface are also available to software control. This makes it very easy to develop a layered application, using well-established building blocks. Callable functions support setting up variables and data acquisition options, and automatically acquiring desired data. Applications may obtain acquired data, perform a fit and retrieve the fit parameters, or provide for a variety of displays and plots. Some applications acquire data through specialized protocols, and then use the Correlation Plots for fitting and display functions.

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Iconic Representation of Particle Beams Using Personal Computers

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Abstract

The idea of representing the character of a charged particle beam by means of its emmittance ellipses, is essentially a mathematical one. For quick understanding of the beam character in a more user-friendly way, unit beam cells with particles having a uniform nature, have been pictured by suitably shaped 3-D solids. The X and Y direction momenta at particular cell areas of the particle beam combine together to give a proportionate orientation to the solid in the pseudo 3-D world of the graphic screen, creating a physical picture of the particle beam. This is expected to facilitate the comprehension of total characteristics of a beam in cases of online control of transport lines and their designs, when interfaced with various ray-tracing programs. The implementation is done in an IBM-PC environment.

Introduction

The practice of representing particle beam in terms of the phase-space figures at an axial location of the beam, is well-established. The phase-space diagrams can be either a plot between x/y and p_x/p_y, where p_x and p_y denote momenta in x and y directions respectively. Consequently these 2-dimensional figures, are used to convey informations about an entity which exists in reality, in a 4-dimensional phase-space consisting of x, p_x, y and p_y as the dimensions. Beam-line designers as well as operators optimizing transport of particles through beam-line elements, very often refer to these 2 dimensional projections idealised to ellipses, to study and optimise the transport of a particle-beam. Any of these ellipses, eg. x vs θ (= p_x/p, where p is the longitudinal momentum), though conveys the information about distribution of a particle-population with specific ranges of x momenta, as a function of x, but it does not immediately produce any idea about their correlations with the y-axis. Conversely, the same inadequacy applies for the y vs ϕ ellipse. Therefore as far as qualitative understanding of the beam is concerned, as a first impression, views of the ellipses are not complete enough. The mental process of a person doing the optimizations has to be only analytical, which is not a very comfortable situation. Consequently, it was thought that a more expressive diagram, which will convey a qualitative idea about all the 4 dimensions of the beam-ellipsoid, should contribute as a more friendly feedback to the user of a transport-optimization procedure.

With the vastly expanding use of computers with image graphics capabilities by transport-line designers and graphic workstations as operators' consoles in accelerator control, the 3-D graphic generation capabilities of these computers, can be tapped in such a situation. The particle beam, if could be made visible together with all its angle,

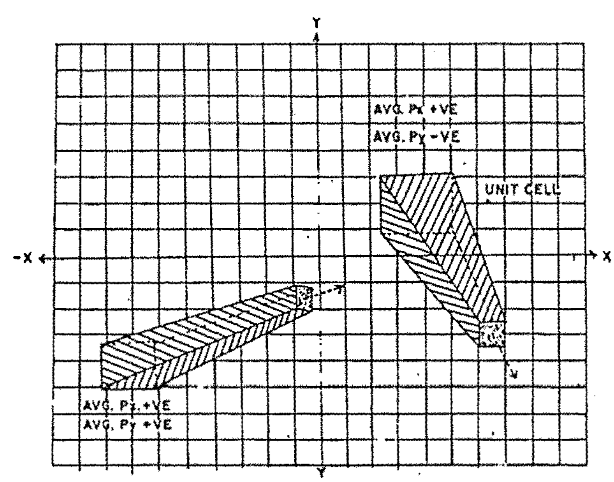

Figure 1. Two beamlets with different momenta

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OBJECT-ORIENTED PROGRAMMING TECHNIQUES FOR THE AGS BOOSTER*

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Abstract

The applications software developed for the control system of the AGS Booster Project was written in the object-oriented language, C++. At the start of the Booster Project, the programming staff of the AGS Controls Section comprised some dozen programmer/analysts, all highly fluent in C but novices in C++. During the course of this project, nearly the entire staff converted to using C++ for a large fraction of their assignments. Over 100 C++ software modules are now available both for Booster and general AGS use, of which a large fraction are broadly applicable tools. The transition from C to C++ from a managerial perspective is discussed and an overview is provided of the ways in which object classes have been applied in Booster software development.

Introduction

At the outset of the Booster Project,[1] management decided to promote the use of object-oriented techniques among the programming staff. Our hope was to achieve improved programming efficiency and greater maintainability of code through increased modularity. The C++ language was chosen because of its accessibility to a staff fluent in C, and because it was well supported on the computing system already in place. Whereas prior efforts at in-house self-education in C++ had yielded only very limited success, our staff now is very comfortable using C++, and we consider that our goals in promoting C++ have been satisfactorily achieved. During the past two years, our programmers have accumulated nearly 200 staff-months of experience with C++, and produced some 160 source-code modules totaling more than 100,000 lines; of these, more than 80 are tool modules which define more than 300 object classes. The Booster was commissioned in June of this year; during this period our software was exercised vigorously, and software performance and user reaction were favorable. The reasons for this success will be discussed below.

Environment

The AGS Distributed Control system (AGSDCS) comprises a network of approximately 50 Hewlett-Packard/Apollo workstation nodes on a Domain token-ring network which spans the AGS accelerator complex. Ten workstations provide the operator interface at five consoles in the AGS Main Control Room. About 15 workstations are used for programmer or physicist development nodes, and the remainder are used as control system consoles by engineering and technician work groups among the accelerator staff, or as data-collection servers in the accelerator complex. The workstations run a Unix-like operating system and provide a high-resolution display, for which an internal Graphics User Interface (GUI) standard for the programs has been established.

The AGSDCS is interfaced to some 5800 accelerator devices via more than 100 so-called "device-controllers" in more than 50 locations. The device-controller layer is currently implemented with Intel Single-Board Computers (SBCs) in Multibus packaging. Device-controllers are connected to so-called "stations" via the GPIB (IEEE-488) bus; stations are implemented either in Multibus SBCs (the older AGS version) or in Apollo workstations (the new Booster version). Access by high-level programs to the network of accelerator devices is supported by a library of toolkit routines which permit a device to be referenced by just its name. The library routines resolve the device address in the network by reference to descriptor tables constructed from a relational database which describes the entire control system.

Transition to C++

A number of factors are discussed here which contributed to the successful transition of the staff to C++. Experience with this process suggests that each factor is important, and that the absence of any one of them would have had a very negative impact on its success.

Assignment Profile

Staff members were given independent software assignments for the Booster Project, and permitted to develop them individually. The opportunity to nurture a new project from its inception without undue burden of prior development encouraged the staff to apply new techniques. In addition, it was recognized early that many of the assignments required common tools, and management fostered cooperative efforts

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A Simplified Approach to Control System Specification and Design Using Domain Modelling and Mapping.

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Abstract

Recent developments in the field of accelerator-domain and computer-domain modelling have led to a better understanding of the "art" of control system specification and design. It now appears possible to "compile" a control system specification to produce the architectural design. The information required by the "compiler" is discussed and one hardware optimization algorithm presented. The desired characteristics of the hardware and software components of a distributed control system architecture are discussed and the shortcomings of some commercial products.

I. INTRODUCTION

In recent years more emphasis has been placed on the gathering and validating of requirements for automated control systems before they are built [1, 2, 3, 4, 5]. Our earlier work reported on the specification of the KAON Factory Central Control System (KF-CCS), using two emerging techniques in the application of object-oriented principles to requirements specification namely: domain driven modelling [2] and dynamic object modelling [3]. A re-examination of the problems encountered using these two contemporary techniques has led to a better understanding of both the use of domains in creating and structuring a system specification and of the design-processes used to transform the system specification into executable code.

It now seems possible to "compile" a control system from its specification form. As with all "compilers" the "target language" (usually a micro-processor machine code) must be *exactly* described before the "compiler" can be created. With contemporary domain modelling approaches we now have the power to construct such a complete description of the active elements that form control systems and to determine an appropriate strategy for "compilation".

II. PROBLEMS WITH EARLIER APPROACHES

Dynamic object modelling [3] advocates, from the outset, the determination of the context of a system-to-be-built and its presentation in the form of a Context Diagram (Fig. 1). A Context Diagram follows from an analysis of a problem, the specification of a solution and the desire to implement the solution as an automated system. This approach leads to an early identification of external devices (Terminator Objects) that are to be interfaced to and controlled by the system. Only information flows between the system and the Terminator Objects are shown on a Context Diagram.The single bubble represents the system-to-be-built; boxes represent Terminator Objects.

The internal structure of the system-to-be-built, termed the Object Communication Diagram, is comprised of both the static and dynamic system-objects in the solution. Figure 2 shows an example internal structure for Fig. 1. Static objects are representation of conceptual entities in the solution (e.g. schedules, lists etc.) while each dynamic object represents the dynamic behavior of its associated Terminator Object, as seen through their mutual interface (the information flows between the dynamic object and the Terminator Object).

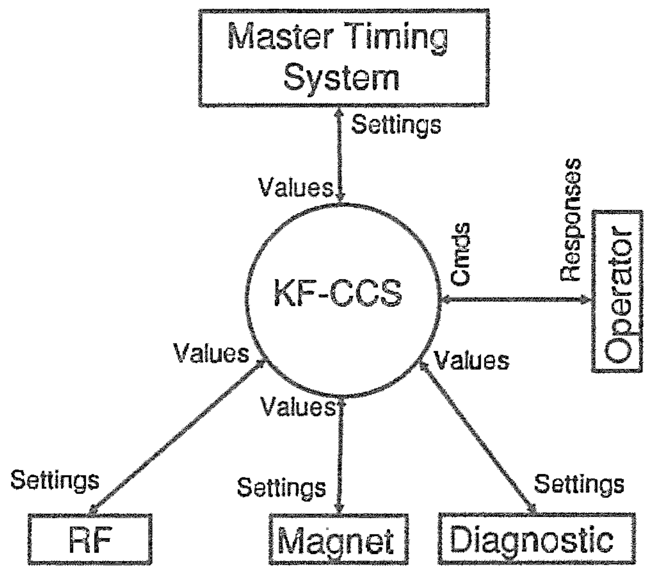

Fig. 1 A simplified Context Diagram of the KF-CCS. The single bubble represents the system-to-be-built; boxes represent Terminator Objects.

During the KAON Factory Study the premature focussing on KF-CCS systems-analysis [3] led to some difficulties with users and reviewers appreciating the role of the (predominantly software based) KF-CCS in the much larger context of controlling KAON Factory beam production, and the affect of interactions between its Terminator Objects. A Super-Context Diagram was therefore created to show the "bigger picture" (Fig. 3). In the KAON Factory, interactions between Terminator Objects will be due, for example, to the Master Timing System that will determine (predominantly in hardware) the exact timing of all beam related events e.g. beam transfers between any of the 5 rings.

Domain driven modelling [2], on the other hand, does not *require* this premature move into systems-analysis. In the early

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The Direct Manipulation Shell: Creating Extensible Display Page Editors

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Abstract
Accelerator controls systems provide parameter display pages which allow the operator to monitor and manipulate selected control points in the system. Display pages are generally implemented as either hand-crafted, purpose-built programs; or by using a specialized display page layout tool. These two methods of display page development exhibit the classic trade-off between functionality vs. ease of implementation. In the Direct Manipulation Shell we approach the process of developing a display page in a manifestly object-oriented manner. This is done by providing a general framework for interactively instantiating and manipulating display objects.

I. Introduction

We are developing a tool, known as the Direct Manipulation Shell (DMS), which will allow the construction of software applications in much the same way as modern hardware devices are constructed. That is, the user selects and combines together software components in an interactive, plug-and-play fashion when developing their applications software. DMS provides an environment in which software components are provided and directly manipulated (hence Direct Manipulation Shell) by the user.

A programming environment developed through DMS contains software components which address the needs of a single problem domain, e.g., accelerator parameter page development. This can be contrasted to a traditional programming environment containing compilers, linkers, editors, etc., which support no specific problem domain and provide no domain specific support for applications development. Using DMS, the user performing the applications programming spends most of his time browsing catalogs of domain specific components rather than developing algorithms and data structures. It is assumed that this applications programmer is knowledgeable in the domain supported by the specific environment, not necessarily in the domain of the computer sciences.

The goal of DMS is to provide users with a software development environment in which they construct solutions in problem domains about which they are concerned and knowledgeable. These domain experts are provided components that are presented and manipulated through terms and concepts found in this problem domain. Using the facilities provided by DMS, programming experts develop a set of interrelated software components which can be used to construct solutions to problems in this domain. This process of constructing a programming environment through DMS is similar to the process of constructing an expert system [2] using an expert systems development shell. When developing an expert system, a team of programmers and domain experts combine efforts to develop a set of rules which address problems in a specific problem domain. With DMS, a team of programming and problem domain experts construct a set of software components which can be accessed and manipulated through DMS. In either case the user is provided with an environment which can be applied to problem solving with little understanding of the underlying computing environment.

Of course, theses goals are not unique to DMS. Basically, DMS provides an interactive, interpreted, object-oriented, programming environment. Usually, such environments have the following major shortcomings:

1. performance.
2. availability of third party, off-the-shelf "components".
3. performance.

For an accelerator control application (1) and (3) (and to a lesser extent (2)) can be killers. The DMS environment is designed to specifically address these limitations. This is achieved in the current version of the DMS tool via the use of a modified Common Lisp [5] interpreter, XLisp [1].

XLisp has incorporate within it an object-oriented language constructs which allow classes to be defined and instances of XLisp object to be created. Our modifications to XLisp enable the user to interactively create and manipulate instances of XLisp objects which in turn create and manipulate instances of C++ objects. This is much more than just a foreign function interface, because the objects thus created are now managed by the DMS environment. This means, for example, that much of the memory management is taken care of automatically (garbage collection). Additionally, DMS knows about C++ data structures, so that unmodified C++ code can be linked directly into the DMS environment. Additionally, because of the object oriented extensions on the Lisp side, one can write straight forward Lisp code without continually bothering about how data is represented.

Within DMS one can move freely between the Lisp and C++ environments, taking advantage of the best features of both. In particular, one may take advantage of the speed and availability of C++ class libraries within an interactive Lisp programming environment. We have, for example,

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Object Oriented Programming Techniques Applied to Device Access and Control

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1 Introduction

Device access and device control is one of the most important tasks of any control system. This is because control implies obtaining information about the physical world by reading sensors and modifying the behaviour of the physical world by sending commands to actuators. At the **European Synchrotron Radiation Facility (ESRF**, ref. [1]) effort has gone into designing and implementing a model for device access and control using as much as possible the latest ideas and methods of Software Engineering. One of the main contributions in recent years to Software Engineering has been in the field of **Object Oriented Programming(OOP)**. Although the philosophy is not new the refinement and application of this methodology on a wide scale is. At the ESRF a model for device access and control has been developed which is based on **OOP** methods. This model, called the **device server model**, is the topic of this paper. The device server model is written entirely in C and is therefore portable. It depends on no other software and can be ported to any machine where there is a C compiler. Because the model is based on **OOP** it presents a *user-oriented* view of the world as opposed to a *software-* or *hardware-oriented* view of the world.

This paper will describe the device server model. It will describe the problem of device access and the advantages of using **OOP** techniques to solve it. It will present the model. The methodology used to implement **OOP** in the device server model called **Objects In C (OIC)** will be described. An example of a typical device server at the ESRF will be presented. The experience gained from the device server model will be discussed. The paper will conclude with a discussion on how the device server model could be standardised to treat a wider range of problems.

2 The Device Access Problem

The problem which the device server model is designed to solve is a problem which every control system is faced with. The problem could be described as – *how to provide access and control for all the physical devices which represent the machine ?*

Unfortunately there is no widely accepted industrial standard for interfacing devices to computers. Although some attempts have been made at defining an industrial standard none of them have succeeded (see [2]). This means that there are about as many ways to interface a device to a computer as there are device suppliers.

The device access problem would be simple if a single standard were adopted for interfacing. In reality however this turns out to be too expensive because it involves extra development costs for the suppliers.

3 The Device Server Model

At the ESRF a unified model (called the **device server model**) has been developed to solve the problem of device access and control. It is unified for two reasons —

- it presents a single interface for upper level applications to all kinds of devices, and
- it defines the framework within which to implement device access and control for all devices.

The model can be divided into a number of basic elements - the *device*, the *server*, the *Objects In C* methodology, the *root class*, the *device class*, *resource database*, *commands*, *local access*, *network access*, and the *application programmers interface*.

3.1 The Model

The basic idea of the device server model is to treat each **device** as an **object** which is created and stored in a process called a **server**.

Each device is a separate entity which has its own *data* and *behaviour*. Each device has a *unique name* which identifies it in network name space. Devices are configured via **resources** which are stored in a **database**. Devices are organised according to **classes**, each device belonging to a class. Classes are implemented in **C** using a technique called **Objects In C**. All classes are derived from one **root** class. The class contains a generic description of the device i.e. what actions can be performed on the device and how it responds to them. The actions are made available

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An Object-Oriented Implementation of the TRIUMF 92 MHz Booster Cavity Control System

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Abstract

A 92 MHz auxiliary accelerating cavity has been designed for installation inside the TRIUMF cyclotron, operating up to a maximum peak voltage of 200 kV. The cavity doubles the energy gain per turn for accelerating hydrogen ions in the energy region of 400-500 MeV, and reduces by 50% the stripping loss of the ion beam. The control system for the booster comprises a PC-based processor in a VME crate, for local control, and a 68030 processor with an ethernet connection as the interface to the TRIUMF Central Control System. The requirements for the booster control system were established by an object-oriented requirements analysis. Afterward, an object-oriented architectural design step was used to produce the processor allocation of the design, which was then implemented using C, for the VME processor, and a commercial database and screen generator product, for the VAX user interface.

I. Introduction

The RF Booster consists of an RF cavity, an RF amplifier, a transmission line connecting the amplifier to the cavity, a local control system and ancillary equipment. The RF cavity is made up of two symmetrical halves which are mounted on the lid and floor of the cyclotron vacuum tank and separated by 64 mm to provide a region free of all components. The accelerating voltage exerted by the RF cavity increases from 0 kV at a beam energy of 330 MeV to a maximum of 150 kV at a beam energy of 520 MeV. The RF cavity geometry is designed so that, when the booster is operating, each ion in the beam receives two impulses during its passage through the cavity. This energy gain enhances the turn separation of the beam, reduces the number of turns made during acceleration and reduces the beam loss due to electromagnetic stripping.

During the design and development of the booster, equipment specialists implemented a local control system based on an IBM-PC in VMEbus. Although this system met the requirements for local control of the booster by equipment specialists located in the RF area, its design did not consider the requirement for remote control by the cyclotron operators.

II. Object-Oriented Analysis

To identify the requirements for remote control of the booster, an object-oriented requirements analysis was carried out using the domain-driven specification techniques described in [1]. For this analysis, the notation of the Yourdon methodology with Ward-Mellor extensions[2] was used to represent objects, their behaviour and their interactions. Objects and their methods were represented by *data flow diagrams* (DFDs), object behaviour was represented by *state transition diagrams* (STDs) or *control transforms*, and information flows between objects were represented by *control* and *data* flows. A relevant aspect of the object-oriented methodology employed for the requirements analysis was the identification of objects which would interact with the RF Booster remote control system via information flows only. Such objects are known as *terminator* objects of the system.

As the only CASE tool available on-site was DECdesign, a CASE tool from Digital Equipment Corporation, this tool was used to capture the models of the booster remote control system. The strict Yourdon-Ward-Mellor methodology implemented by this tool did not easily accommodate the object-oriented paradigm chosen for the requirements analysis. As a consequence of this inflexibility, the desired goal of a purely object-oriented requirements document was contaminated by tool-specific considerations.

The DECdesign *verification* utility, however, proved invaluable in ensuring that control and data flows between objects were consistent and in ensuring that the data dictionary was maintained up to date.

III. The RF Booster Remote Control System

During the domain analysis it was recognised that personnel operating the booster would play two roles in their interaction with the booster: that of a *beam control* operator, whose only concern would be the affect of the booster on the beam, and the role of *equipment management operator*, whose concern was the management of the booster equipment.

These operator roles enabled the identification of the two domains spanned by the RF booster remote control system: the domain of beam control and the domain of equipment management. In the former domain, the requirements of the remote control of the RF booster by an *RF Booster Beam Control System* (RFB BCS) were examined and, in the latter domain, the requirements for remote management of the booster equipment by an *RF Booster Equipment Management System* (RFB EMS) were examined.

A. The RFB Beam Control System

Given the preceding assumptions, the purpose of the RFB BCS was described as follows:

- to enable operators in the Cyclotron Control Room to remotely control the phase and amplitude of the booster, and
- to provide operators in the Cyclotron Control Room with a meaningful display of the booster operating parameters necessary for remote control and monitoring of the booster.

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The State Manager: A Tool to Control Large Data-Acquisition Systems

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Abstract

The State Manager system (SM) is a set of tools, developed at CERN, for the control of large data-acquisition systems. A dedicated object-based language is used to describe the various components of the data-acquisition system. Each component is declared in terms of finite state machines and sequences of parametrized actions to be performed for operations such as the start and end of a run. The description, written by the user, is translated into Ada to produce a run-control program capable of controlling processes in a distributed environment. A Motif-based graphical interface to the control program displays the current state of all the components and can be used to control the overall data-acquisition system. The SM has been used by several experiments both at CERN and other organizations. We present here the architecture of the SM, some design choices, and the experience acquired from its use.

I. INTRODUCTION

Today's large data-acquisition systems are composed of an increasingly large set of programs which prove difficult to control. Furthermore, the different programs are not independent but co-operate and need to be synchronized: for example, they must be started and stopped in a given order. Finally, a system composed of many different programs is difficult to operate if one has to interact with each of these programs.

The SM [1,2] is a neat and flexible solution to this problem. It is a tool for building distributed run-control systems by means of a dedicated object-based language.

The system to be controlled is decomposed into a set of objects. Objects correspond to a part of the system: a program or a subsystem. Each object must then be described as a state machine, its main attribute being its current state. The state can take any value in a list of values declared by the user in his SM program. An object can interact with other objects by sending commands to them. The command triggers the execution of an action, which is terminated when the object reaches a new state.

Each activity of the data-acquisition system to be controlled should be handled by a single process. These processes are called associated processes because they are associated with an SM object. The SM communicates with them via messages handled by the OSP package [3]. The SM sends the commands triggering the execution of actions, and the associated processes reply when they assume a new state. These messages constitute the interface between the SM and the associated processes. The same interface is used by an overall control program to send commands to the SM itself as shown in Figure 1.

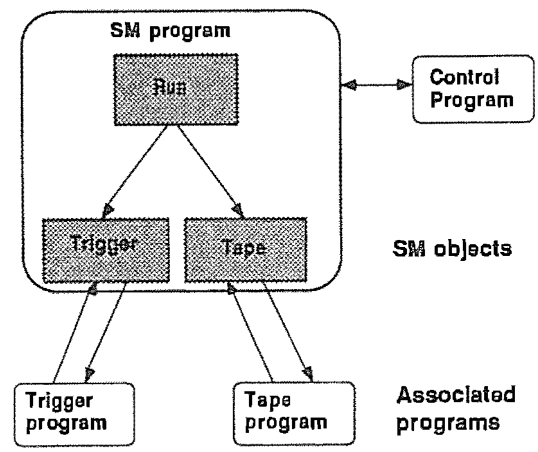

Figure 1. The SM program and the external world.

The communication package deals with distributed environments and thus allows commands to be sent to processes running on remote machines.

The objects are divided into two categories:

- The associated objects are associated with a program dealing with a device or an activity.

- The objects of the second category correspond to abstract entities that form part of the description of the system. They are internal to the SM.

The SM program written by the user is translated by the SM translator into Ada [4]. This Ada code is then compiled and linked to produce an executable image. The execution of this image will activate the run control and establish the communication with the associated processes.

II. THE SM LANGUAGE

A. Object declarations

The SM language contains declarations and instructions. The declarations are used to define the name of an object, its states, and actions. An example of a state machine for an object 'RUN' is given in Figure 2.

The corresponding SM declarations are:

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CASE in CERN's Accelerator Sector

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Abstract

As in the software industry where computer aided software engineering (CASE) methodologies and tools are commonly used, CERN endeavours to introduce this technology to improve the efficiency of designing, producing and maintaining software. A large project is currently under development in the administrative area whereas a dedicated group has been set up to evaluate state of the art techniques for software development relating to physics experiments. A similar activity, though on a smaller scale, has been initiated in the accelerator sector also in view of the large amount of software that will be required by the LEP200 and the LHC projects. This paper briefly describes this technology and gives an account of current experience with the use of CASE methods and tools for technical projects in the accelerator sector at CERN.

1. Introduction

Software engineering is the application of techniques which lead to the implementation of better quality software. It implies a planned process of producing well-structured, reliable, good quality, maintainable software systems which corresponds to the users' needs, within reasonable time frames [1].

This definition suggests that software engineering includes a good deal more than just producing computer programs and that good software development includes documentation, databases, operational procedures, etc. Furthermore, it focusses the planned aspect of the process: as any other engineering discipline, software production should be properly managed with scope definition, specification analysis, cost estimation, production plans, role distribution, etc.

According to industry statistics, 75% of custom software development projects are rejected because they came either too late to be useful or did not correspond to the users' needs. However the complexity of application software grows continuously and today's average business package takes 32,000 man-days, i.e. 160 man-years to develop [2]. This is not dissimilar to the effort spent at CERN on application software for accelerators. Indeed, in the eighties at least 500 man-years were invested on controls and database applications for the PS accelerator complex, SPS and LEP, not including numerous developments that have not been accounted for. The annual maintenance effort is estimated to be around 15% of the development effort and exceeds the production capacity of the groups in charge. Here, maintenance is defined as software repair and update resulting from a changed functional specification of the software product. For each new development the volume of the software increases because more sophistication is required. By the time the LHC is approved, the demand for application software may well be two to three times higher because of increased functionality, increased information volume, more severe execution time constraints due to the superconducting nature of the machine, and higher reliability [3]. Even if the groups in charge manage to develop such large packages with the help of professional, voluntary and temporary staff, they will only be able to maintain it if software of sufficiently good quality is produced so as to dramatically reduce its maintenance cost.

2. What is CASE ?

CASE stands for Computer Assisted Software Engineering.

For each new software project the engineer is recurrently performing a number of similar activities: collecting information from his client, organizing that information, cross checking with the client, etc. The process is systematic, iterative and proceeds in increasing degree of detail. A number of methods and procedures could be derived which, because of their recurrence, would be more efficiently executed if assisted by computer programs. Software tools were thus developed to assist the software engineer in collecting, organizing, storing, retrieving and cross checking that information throughout the development process of his project. The information is introduced through graphical and alphanumerical user interfaces and recorded in a repository, possibly a database management system, so that it is available throughout the production life cycle for complementing, checking and various administrative operations.

CASE is introduced in order to encourage better quality designs, to increase productivity and to render software projects more manageable. Better quality software leads to reduced maintenance: industrial companies e.g. BBC, now ABB, claim to be able to reduce the maintenance to 2% of the development cost by using such tools [4].

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Automation From Pictures: Producing Real Time Code from a State Transition Diagram*

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Abstract

The state transition diagram (STD) model has been helpful in the design of real time software, especially with the emergence of graphical computer aided software engineering (CASE) tools. Nevertheless, the translation of the STD to real time code has in the past been primarily a manual task. At Los Alamos we have automated this process. The designer constructs the STD using a CASE tool (Cadre Teamwork) using a special notation for events and actions. A translator converts the STD into an intermediate state notation language (SNL), and this SNL is compiled directly into C code (a *state program)*. Execution of the state program is driven by external events, allowing multiple state programs to effectively share the resources of the host processor. Since the design and the code are tightly integrated through the CASE tool, the design and code never diverge, and we avoid design obsolescence. Furthermore, the CASE tool automates the production of formal technical documents from the graphic description encapsulated by the CASE tool.

I. INTRODUCTION

Structured analysis and design methods often make use of the state transition diagram (STD) to model real time systems.[1] A CASE tool, such as Cadre Teamwork/RT[2], can partially automate the STD methodology, but the programmer is left with the task of converting the STD into run time code. The programmer takes into account numerous factors, such as task priority, task synchronization, and pending for multiple events, to produce efficient code, and often the resulting code bears little resemblance to the STD. Using a two-step procedure, we have achieved significant automation of this process.

The translation of the STD into code is based on work done previously to develop a language that is based on the STD paradigm. The state notation language (SNL) [3] was developed to simplify programming of time-constrained sequential operations that are driven by events. During extensive experience with the SNL on the Ground Test Accelerator and the Advanced FEL at Los Alamos,[4,5] the SNL evolved into a powerful tool for implementing real time, automatic control. Subsequently, we developed a tool to capture relevant coding information about the STD within the CASE environment and translate it into SNL syntax. Below, we describe the salient features of the SNL, and explain how the translator is used to produce a complete SNL module from the STD.

II. STATE NOTATION LANGUAGE

We designed the SNL to be consistent with the STD methodology and applicable to the existing run time environment that we use at the Los Alamos National Laboratory.[6–8] Following the Mealy convention for STDs, we specify both the events and the actions on the transition between states, and allow only the state name to appear in the state as in Figure 1.

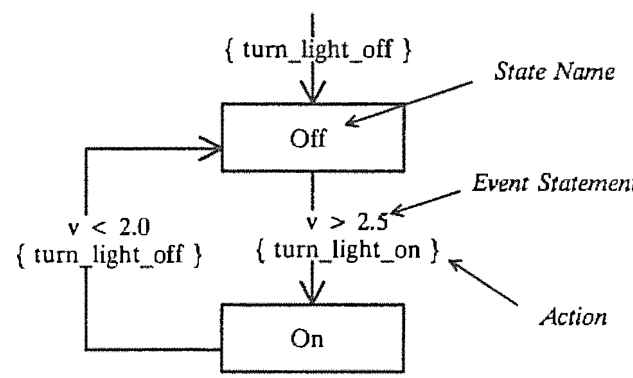

Figure 1. Example of a State Transition Diagram.

In the above example there is only a simple relational expression, which involves one event, the change in the value of variable "v". The SNL is designed to handle more complex event expressions, as well as multiple events. Events may be associated with database channels and time delays. Actions may include calculations, outputs to database channels, and calls to procedures.

Rather than invent yet another new language, we based the SNL on a comprehensive subset of C, along with some relatively minor additions to handle events, actions, and states. We simplified the coding by allowing the programmer to associate run time database channels with a C variable. Figure 2 shows the complete program that implements the STD in Figure 1 in SNL syntax.

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SSC Lattice Database and Graphical Interface

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Abstract

The SSC lattice database and the graphical tools used to access it are discussed.

I. INTRODUCTION

When completed the Superconducting Super Collider will be the world's largest accelerator complex. In order to build this system on schedule, the use of database technologies will be essential. In this paper we discuss one of the database efforts underway at the SSC, the lattice database. The original work on this database system began at the SSC Central Design Group and is described in reference [1].

The SSC lattice database provides a centralized source for the design of each major component of the accelerator complex. This includes the two collider rings (top and bottom), the High Energy Booster (HEB), Medium Energy Booster (MEB), Low Energy Booster (LEB) and the LINAC as well as transfer and test beam lines.

These designs have been created using a menagerie of programs such as SYNCH, DIMAD, MAD, TRANSPORT, MAGIC, TRACE3D and TEAPOT. However, once a design has been completed, it is entered into a uniform database schema in the database system.

In section II we further discuss the reasons for creating the lattice database and its implementation via the commercial database system SYBASE[2].

Each lattice in the lattice database is composed of a set of tables whose data structure can describe any of the SSC accelerator lattices. This data structure will be discussed in section III.

In order to allow the user community access to the databases, a programmatic interface known as dbsf (for database to several formats) has been written. This interface is the subject of section IV. dbsf creates ascii input files appropriate to the above mentioned accelerator design programs. In addition it has a binary dataset output using the SDS (Self Describing Standard) data discipline provided with the ISTK (Integrated Scientific Tool Kit)[3] software tools.

In section V we discuss the graphical interfaces to the lattice database. The primary interface, known as OZ, is a simulation environment as well as a database browser.

OZ has been created using techniques of object oriented modelling and coded in C++ using the ISTK software

*Operated by the Universities Research Association, Inc., for the U.S. Department of Energy under Contract No. DE-AC35-89ER40486.

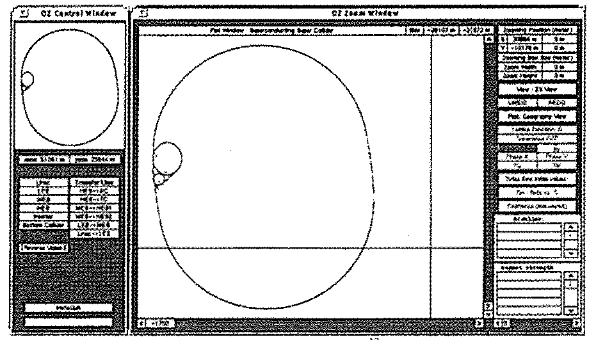

Figure 1: Control and Display Windows of OZ

tools. OZ is SSC specific in that it presents a geometrical view of the collider complex from which one may select the lattice of interest. This geometrical data is also the source of the data used to site the complex geographically. OZ is an interactive simulation environment in which the user can change various parameters such as a steering magnet's field strength and then see whether a beam of given emittance will survive its propagation within a fixed spatial aperture.

In addition to the geometrical view of the complex, one also needs a more abstract view of a lattice structure, and this is provided by a program known as LATVIEW. Because the beam line hierarchy implicit in an accelerator design can be highly nonintuitive, LATVIEW gives an interactive graphical view of this hierarchy.

II. PHILOSOPHY

We have implemented the lattice database using a relational database management system (RDBMS). The particular software system currently used is SYBASE operating within a UNIX workstation computing environment. By putting the lattice information within a RDBMS tied to a network, essentially universal access to the data can be supported. In addition by maintaining a uniform description of the lattice information, various groups such as mechanical and civil engineering, survey and alignment as well as diagnostics and simulation can be coupled to the same data in an efficient manner thus reducing the probability that different groups will use incompatible design information.

In addition, because accelerator design is usually done with a variety of design codes such as the ones mentioned earlier, a lattice database of some kind is the only way to

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Framework for Control System Development*

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Abstract

Control systems being developed for the present generation of accelerators will need to adapt to changing machine and operating state conditions. Such systems must also be capable of evolving over the life of the accelerator operation. In this paper we present a framework for the development of adaptive control systems.

I. INTRODUCTION

Several of the new generation of control systems hardware being developed today have the capability of fast, sophisticated control at all levels in the control hierarchy[1][2]. These systems are typically hierarchical and highly distributed with extremely high I/O throughput.

We have initiated the design of a framework for control system development which can accommodate the new architectures. This paper will present requirements, design decisions, and specifications that we have devised for this framework.

II. REQUIREMENTS

A. *Adaptive*

The control system must be adaptive. It must be capable of growth, evolution, and learning (supervised and self-taught).

The software for these systems is complex and generally in continuous development. The control system must be capable of growth during both commissioning and operational phases.

Many new control system algorithms such as model-based control, expert systems, neural networks, and fuzzy logic are emerging which look very promising in the accelerator control environment.[3][4][5][6]. A mechanism is required which is capable of evolution to accommodate these new control theories. The system must also be capable of arbitrarily complex combinations of these algorithms.

Most of these new control system algorithms are capable of either supervised or self-taught learning. This should prove to be extremely useful as an aide to finding 'golden *orbits*' in storage rings or as a means of reducing the complexity of data presented to the operator. The control system must facilitate this mechanism.

B. *Hierarchical*

The control system must support a hierarchical control structure. It must be capable not only of supporting the 'standard' supervisor-cell-local type of hierarchical control[7], but also each layer must be divisible into local subhierarchies. This latter requirement facilitates the incorporation of cascaded and adaptive control algorithms.

C. *Distributed*

The control system must support the underlying distributed hardware.

Many computer systems provide basic networking support. The control system must also incorporate mechanisms for the registration of computing services, the automated association of client and server, and the uniform representation of data transmitted between heterogeneous systems.

The control system must be designed to accommodate the known features of distributed control - such as error detection and recovery, virtual time synchronization, nondeterministic networks, concurrency, resource protection, and bandwidth-limited messaging.

D. *Operational Continuity*

The control system must support operational continuity. It must provide for dynamic, and transparent switching between compatible modules without interrupting operation.

Transparent switching is required to permit the exchange of control modules in the event where the system operation exceeds the bounds of the previous controller. This should be possible without bringing the system down and without leaving the machine uncontrolled. Sufficient machine state information should be transferrable to provide for 'bumpless' switching.

E. *Dynamic Association*

The control system must support the dynamic association of applications. Links between the control system and the application should be redirectable during normal operations. This is essential to provide for independent development of associated modules and also to provide support for the adaptive and operational continuity requirements listed above.

Dynamic association permits both application and control modules to be constructed without prior availability of the associated modules. Moreover, for client-server associations, the link process should not require specific knowledge of the server module (capability-based binding). It should be sufficient to specify the type of module and its interface, leaving the association mechanism to a third intermediate process.

F. *Universal Graphical API*

The control system must support a universal graphical application programming interface (API). Regardless of the operating system, windowing system, or window manager, the graphical application programming interface should be identi-

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The LEP Model Interface for MAD

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Abstract

During machine studies and trouble-shooting in the LEP machine various optical parameters must be computed, which can be found quickly using the MAD program. However, the LEP operators are not all well acquainted with MAD. In order to ease their task, a simple interface called the LEP model has been written to run on the Apollo workstations of the LEP control system. It prepares jobs for MAD, sends them to a DN 10000 node for execution, and optionally plots the results.

The desired machine positions and optical parameters vary between LEP runs. The LEP model contains a powerful selection algorithm which permits easy reference to any combination of positions and optical parameters in the machine. Elements can be chosen by name, by sequence number, or by element class. The choice of optical functions includes closed orbit, Twiss parameters, betatron phases, chromatic functions, element excitations, and many more. Recently matching features have been added.

Communication with the control system and with MAD uses self-describing tables, i. e. tables whose columns are labelled with their name and a format code. Experience with this LEP model interface is reported.

1 Introduction

This section describes those aspects of the LEP control system and of MAD which are relevant to the LEP model program. The second section outlines features of the LEP model program. The third section discusses implementation, and the last two sections present future plans and experiences with the program.

1.1 LEP as seen from LEP Model

The LEP control system [1] is based on a network of Apollo workstations connected in a token ring network. The workstations are running under UNIX. They talk to the LEP machine over various links and microprocessors. For time-intensive tasks the network contains an Apollo DN 10000 computer, whose speed is about a factor 1/2 of the IBM 3090.

The descriptions of the LEP machine and of its possible optical configurations reside in an Oracle database. From the database a structural description of LEP is available which is formatted in MAD input language.

For equipment control the access to the Oracle database is too slow. A set of files, known as the "reference data set", is thus extracted and stored in a file server. Most of these files are self-describing tables, known as TFS tables (Table File System [5]). Each table has an arbitrary number of descriptors, and each column is labelled with its name and format code.

The status of equipment, e. g. the magnet excitations, or the RF cavity settings, can be acquired via specialized programs and is usually stored in TFS format. TFS tables can also be sent to LEP to modify the settings of equipment.

1.2 MAD seen from LEP Model

The MAD program [2, 3] has been used extensively for the design of LEP. It is based on a "standard language" [4], used to describe the machine structure, and to request various computations on this structure. The language is designed to make communication with a human user easy. For communication with other programs MAD also understands TFS format.

In the framework of the LEP Model Program MAD serves the following purposes:

- Compute the closed orbit,
- Compute optical functions over parts of the machine,
- Match optical functions to specific conditions,
- Calculate global parameters of LEP,
- Change machine parameters to study their effect.

2 The LEP Model Program

2.1 Tasks

Based on the above, the LEP Model Program must

- Use the reference data set to build menus of available optical configurations and to present them to the user for choice. In this way the program needs no changes if new configurations are installed. The proposed default is taken from a file known as the LEP Run-Table.

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Optimization of Accelerator Control

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I. INTRODUCTION

Expensive exploitation of charged particle accelerators is inevitably concerned with requirements of effectively obtaining of the best characteristics of accelerated beams for physical experiments.

One of these characteristics is intensity. Increase of intensity is hindered by a number of effects, concerned with the influence of the volume charge field on a particle motion dynamics in accelerator's chamber. However, ultimate intensity, determined by a volume charge, is almost not achieved for the most of the operating accelerators. This fact is caused by losses of particles during injection, at the initial stage of acceleration and during extraction. These losses are caused by deviations the optimal from real characteristics of the accelerating and magnetic system. This is due to a number of circumstances, including technological tolerances on structural elements of systems, influence of measuring and auxilliary equipment and beam consumers' installations, placed in the closed proximity to magnets, and instability in operation of technological systems of accelerator.

Control task consists in compensation of deviations of characteristics of magnetic and electric fields by optimal selection of control actions. As for technical means, automatization of modern accelerators allows to solve optimal control problems in real time. Therefore, the report is devoted to optimal control methods and experimental results.

II. METHODS AND PRINCIPLES OF CONTROL ORGANIZATION

Tasks of the accelerating complex systems control are stated as tasks of extremal control. The following stages may be determined in solving of these tasks:

– study of accelerator as an object of automatic optimization;
– selection of methods of optimization and tracking of extremum;
– comparative study of methods, using models, which have the main peculiarities of the control object;
– synthesis of extremal control algorithm and procedure of estimations of automatic adjustment efficiency at operating accelerator.

Solution of a task can be shown as an example of extremal control of accelerated beam intensity for a proton synchrotron at the Institute of Theoretical and Experimental Physics (Moscow).

Intensity of a beam, injected into the ring, is a function of 11 independent variables, normalized with respect to injector current:

– electrostatic injector voltage;
– injection field intensity;
– radio frequency adjustment in the form of delay of the master clock start;
– correction currents of beam orbit.

Process of intensity change is characterized by spontaneous drift (10 – 12% shift), which can be compensated by varying of the above mentioned variables. Dispersion of an interference is selected in accordance with a noise level, reduced by averaging of beam intensity measurements at the accelerator to 3%.

Criteria of preliminary selection of optimization methods were algorithm discreteness, caused by cyclic processes in the accelerator, as well as convergence in conditions of substantial noises, high speed, minimality of spread in magnitudes of an output value during tuning, compactness of control program.

An important peculiarity, determining selection of a method, is a problem of creation of adequate mathematical description, that forces us to consider an object as a "black box". In this case it is necessary to use search step methods.

It should be noted, that for the use of these methods a necessary condition of object parametrization is satisfied. The condition consists in definiteness of controlled variables, whose varying enables reaching of extremum.

As competitive methods have been selected method of sequential simplex planning, including automatic selection of a step, and methods of random search in modifications:

– with estimation of gradient
– with self-learning
– with punishment of randomness

Values of methods parameters, ensuring a stable convergence and the highest speed in conditions of interferences at models (1) have been determined at the first stage of the studies. In this case a higher speed of the method of sequential simplex planning and higher reliability of extremum search may be noted. One should consider a higher sensitivity in estimation of direction near the extremal zone and complete set of an operating program as the advantages. It is obvious, that it is extremely important to know efficiency characteristics of a priority selected optimization methods, obtained in conditions, near to existing at the object. Comparative studies with the use of models were carried out in the following conditions:

Task of maximization of a single-extremum scalar function

$$I(X) = E_{\xi}\{Q(X,\xi)\}$$

in situation of noise is considered. Here, $X = (x_1, \cdots x_n)$ is a vector of controlled variables, which are subject to determination. Functional $Q(X,\xi) = I(X) + \xi$ is considered to be measured during optimization. Here ξ is a random value, distributed normally with the expectation, equal to zero, and dispersion σ^2.

Extremum of the function I(X) is determined in the specified region

$$X_i^{min} < X_i < X_i^{max}, \qquad i = 1, 2 \cdots n$$

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MODELLING AND OPTIMIZATION OF BEAMS DYNAMICS IN LINAC

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Abstract

Problems of acceleration and focusing in linear acceleratirs are considered. A general mathematical problem of charged particle beam control is formulated. Methods and algorithms of solving these problems are developed. Problems of mathematical simulation of beam dynamics are discussed in detail. Some beam quality functionals depending on all particle tracks are propossed. Mathematical methods are used for choosing parameters of forming systems. Designed codes allow to simulate and optimize beam dynamics.

This report is devoted to the realization of general approach to problem of dynamical system trajectories control in accelerating and focusing structures.

Let us consider the system of differential equatios

$$\dot{X} = f(t, X, u), \qquad (1)$$

where t is time, X is R^n vectir of phase coordinates, u is R^r control vector and f is vector function. We assume that system (1) has the solution $X = X(t, t_0, X_0)$ with initial conditions $X(t_0, t_0, X_0) = X_0$ for $X_0 \in M_0$, where M_0 is the set of initial values. Let us denote $M_{t,u}$ the shift of set M_0 through trajectories of system (1). Let us suppose that the function $\rho(t,X) \geqslant 0$ is the system (1) integral invariant and functions $\Phi(t,X,\rho)$ and $G(X,\rho)$ are given and non-negativ.

The main problem is to find the control $u = u(t)$, $t \in [t_0, T]$, that gives infimum to the functional

$$I = \int_{t_0}^{T} \int_{M_{t,u}} \Phi(t, X_t, \rho(t, X_t))\, dX_t\, dt + \int_{M_{T,u}} G(X_T, \rho(T, X_T))\, dX_T. \qquad (2)$$

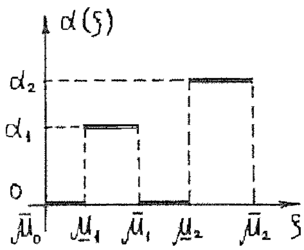
This general approach is used for the charged particles beam control in LINAC [1,2].

Let us consider formulations of cotrol problems related with formating of required accelerating, bunching and focusing regimes for charged particles beams.

The longitudional dynamics of the beam in accelerators with drift tubes may be described by well known equations

$$\frac{d\gamma}{d\xi} = \alpha(\xi)\cos\varphi, \quad \frac{d\varphi}{d\xi} = 2\pi\gamma/\sqrt{\gamma^2 - 1}, \qquad (3)$$

where γ is energy and φ is particle phase, $\xi \in [0, L]$, is longitudional coordinate, L is the length of the structure. In the equation (3) piece-wise constant function $\alpha(\xi)$ is defined by formulas



$$\alpha(\xi) = \begin{cases} 0, & \xi \in [\bar{\mu}_{i-1}, \mu_i], \\ \alpha_i, & \xi \in [\mu_i, \bar{\mu}_i]; \end{cases}$$

$$i = 1, 2, \ldots, N; \quad \mu_0 = 0; \quad \mu_N = L.$$

and proportional to intensity of accelerating field. Let us suppose that energy $\hat{\gamma}$ and phase $\hat{\varphi}$ of particles at the end of acceleratir are given or equal to average particles energy and phase correspondingly. The minimization of functional

$$I = \int_{M_{L,\alpha}} \left[a\left(\frac{\gamma_L}{\hat{\gamma}} - 1\right)^2 + b(\varphi_L - \hat{\varphi})^2 \right] d\varphi_L\, d\gamma_L \qquad (4)$$

that characterizes the beam at the end of accelerator, provides optimal parameters.

Let us consider the radial motion now. Let variables η and $æ$ are reduced radial coordinate and velocity of a charged particle correspondingly. Then equations (3) are copled with system

$$\frac{d\eta}{d\xi} = æ;$$
$$\frac{dæ}{d\xi} = -\alpha(\xi)\left(\cos\varphi \frac{\gamma æ}{\gamma^2 - 1} - \frac{\eta \sin\varphi}{\sqrt{\gamma^2 - 1}}\right) - U(\xi)\frac{\eta}{\gamma^2 - 1} \qquad (5)$$

where piece-wise function $U(\xi)$ is intensity of solenoid longitudional magnetic field. To

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Development of a Diagnostic System for Klystron Modulators Using a Neural Network

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Abstract

The diagnostic system for klystron modulators using a neural network has been developed. Large changes in the voltage and current of the main circuit in a klystron modulator were observed just several ten milli-seconds before the modulator experienced trouble. These changes formed a peculiar pattern that depended on the parts with problems. Diagnosis was possible by means of pattern recognition. The recognition test of patterns using a neural network has shown good results. This system, which is built in a linac control system, is presently being operated so as to collect new trouble patterns and to carry out tests for practical use.

I. INTRODUCTION

In the electron linac, high-power klystrons are used as an amplifier that provides rf power to accelerate electron beams. Five modulators driving five klystrons are installed at Tohoku University's 300 MeV electron linac.

Since a klystron modulator, which generates pulsed power output of high voltage and a large current, is operated under severe conditions, it has problems most frequently among the devices in a linac. The Tohoku linac is at fist adjusted by the accelerator group and is then operated under regular conditions by experimentalists who use the linac for their experiments. However, they are not always specialists in the accelerator field. When the various devices comprising a linac have problems, it is necessary to install support systems for linac operation in order to suitably dispose of these problems and to continue linac operation. Therefore an expert system for the diagnosis of beam operation [1] and the diagnostic system for a klystron modulator have been developed.

In designing this system, it was noticed that large changes in the voltage and current of the main circuit in a klystron modulator existed just several ten milli-seconds before the modulator had a problem. These changes formed a peculiar pattern that depended on the parts with problems. Some interesting patterns were observed in preliminary tests [2]. Diagnosis was possible by means of pattern recognition. A neural network having an excellent ability for pattern recognition was used for comparisons between learned and actual patterns. It was useful to apply the neural network to this system in order to improve the accuracy of the diagnosis, to simplify diagnostic programs and to reduce the development period. In order to increase the accuracy of this system, more trouble patterns should be learned; as of now, very few patterns

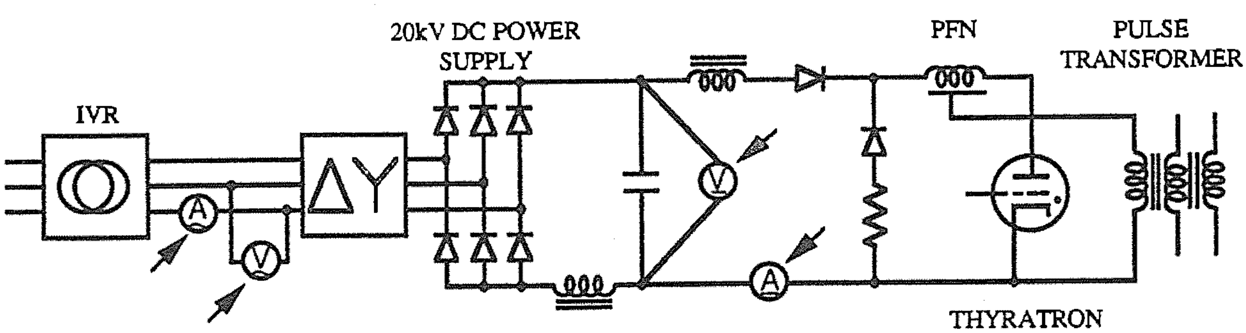

Fig.1. The klystron modulator circuit.

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Diagnostic Expert System in the PF LINAC

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Abstract

A prototype diagnostic expert system (ES) was developed for the Photon Factory 2.5-GeV electron / positron LINAC injector system. The ES has been on-lined with the conventional linac computer network for receiving real data. This project was undertaken in an attempt to reduce the linac operator's mental workload, diagnosis duties, and to explore Artificial Intelligence (AI) technologies.

The outlook for ES and its problems, and what has been achieved are outlined in this presentation.

I. Introduction

Diagnostic problems are relatively well understood both empirically and theoretically. A variety of shells / tools are available on the market to facilitate the implementation of diagnostic systems. We have developed several diagnostic ES for the LINAC and some are now under operation. Having gained experience through previous projects, we built a new hybrid ES this time. The application described here is an ES for the injector system of the Photon Factory (PF) LINAC[1-4], which is being operated a total of 5000 hours per year, making injections to the PF storage ring and the TRISTAN e+/e- collider. Accelerators (LINAC) are complex devices, using many thousands of components. We have been looking for appropriate expert system shells and tools with which we can easily and rapidly establish an expert system. For several years, a small ES based on a personal computer was used for exploring applications of AI techniques. A prototype diagnostic system has been built in order to determine whether or not the various problems can generally be solved using an ES frame-work; a knowledge base (K/B) for the accelerator domain and task analysis were also investigated in this project.

II. Why we need ES for the accelerator

When any fault or trouble occurs in the LINAC, the operator is required to recover the system, even at midnight, even though, he may not be an expert regarding many of the fields required to diagnose the specific trouble.

Diagnosing faults in a complex process is a task that requires experience and considerable knowledge in many fields. Thus, any assistance given to the linac operator regarding diagnosis and operation is extremely desirable.

When human experts are scarce, and when problems must be solved for which there are no established solutions or exact theories for problem solving, an expert system seems to be appropriate. When there are several candidate procedures, or algorithms, involved in problem solving. Also, ES should be useful and more efficient than conventional programming.

Since most ES are flexible, if we change the physical structure of the accelerator, the K/B can be gradually extended by adding new knowledge while being refined. Programming costs will be minimized by using ES. This is the essential advantage of an expert system.

III. Definitions of AI

Some people think that "AI by itself can solve all of the problems." We must be very careful concerning this idea. AI is not magic, and its capability is still limited in solving practical problems . On the other hand, there are other people who believe that AI can do nothing worth while at all. We, thus, need to define AI before any discussion.

We have seen many definitions. People's dreams are big, and they could have answered that "Artificial Intelligence is the science of constructing a thinking machine."

Marvin Minsky gave a new definition: "Artificial Intelligence is the science of making machines do things that would require intelligence if done by men".

Today, the abbreviation "AI" is used with the meaning of "Advanced Information processing technology". From this perspective, AI will certainly become more and more important in the Accelerator domain.

We discuss here only knowledge-based systems which are a subset of AI technology. In most cases, ES is a rule-based production system which dispenses with specialized knowledge of a well-defined domain.

It is said that ES belongs to the most important developments of a new type of software generation.

IV. History of AI

It should be mentioned that AI is still very young. Fundamental AI researches are necessary for continuously defining and realizing AI's future.

The term "Artificial Intelligence" was invented at the Dartmouth Conference in 1956, where John McCathy (Stanford) and Marvin Minsky (from MIT) were participants. After that, a new field of research was born.

The feasibility of the first expert system was demonstrated in the 1970's under the leadership of Edward Feigenbaum. There have been many successful ES in the past. If we classify the

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GLAD: A GENERIC LATTICE DEBUGGER*

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Abstract

Today, numerous simulation and analysis codes exist for the design, commission, and operation of accelerator beam lines. There is a need to develop a common user interface and database link to run these codes interactively. This paper will describe a proposed system, GLAD (Generic LAttice Debugger), to fulfill this need. Specifically, GLAD can be used to find errors in beam lines during commissioning, control beam parameters during operation, and design beam line optics and error correction systems for the next generation of linear accelerators and storage rings.

INTRODUCTION

I have been asked to present a paper on Model-Based methods and Artificial Intelligent (AI) methods for accelerator control. Being a teacher of T'ai Chi, a system of Chinese exercises based on the Yin and Yan principle, I am familiar with the Taoist saying:

Tao is Yin and Yan

It is natural for me to think of Model-Based methods and AI methods as one system of methods—the GLAD system. While thinking about the GLAD system, I made a list of the Yin and Yan pairs associated with accelerator control:

Yin	Yan
Beam line	Beam
Design	Control
High-level	Low-level
Commission	Operation
Play back	Real time
Beam	Parameter
Element	Strength
Look	Adjust
Off-line	On-line
Inverse-Modeling	Modeling
Interpretation	Analysis
Automatic	Manual
Solution	Problem
Rule-based	Trial-and-error
Prediction	Validation
Future	Present
Waste Prevention	Risk Reduction

The purpose of this paper is two-fold: (1) to describe the Model-Based control philosophy in terms of these Yin and Yan pairs, and (2) to propose the GLAD method as a practical way to upgrade any existing accelerator control system to become an intelligent Model-Based control system.

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THE TAO OF MODEL-BASED CONTROL

The Tao of Model-Based Control is a generic way of controlling beam parameters using modeling and simulation codes interactively during commissioning and operation of a beam line.

Beam Line Design and Beam Control Codes

Every accelerator or storage ring system consists of a charged particle beam propagating through a beam line composed of bending, focussing, and accelerating elements. In the design stage, the effects due to errors in the beam line are simulated using modeling codes. For example, modeling codes are used to design an orbit correction system consisting of dipole correctors and beam position monitors (BPMs). During commissioning and operation, these same modeling codes can be used to find the errors in the beam line elements and to control beam parameters interactively.

High-level and Low-level Software

The software of a Model-Based control program can be divided into high-level and low-level software. High-level software is the modeling and simulation code for the design and control of an accelerator beam line. Low-level software is the application code for setting the strengths of the beam line elements and measuring the beam parameters.

Commissioning and Operation Goals

High-level software can be subdivided into two types: one for commissioning and the other for operation. The goals of commissioning and operation are not the same. The goal of commissioning is to find the causes of measured beam errors, while the goal of operation is to correct the error effects on the beam.

Here is one example. Often beam orbit errors are caused by magnet misalignments and BPM reading errors. During commissioning, it is necessary to first use orbit simulation codes to find errors in the beam line elements (the sources). After these errors are found in the beam line elements, they can be incorporated directly into the "as-built" model. During operation, the same orbit simulation codes can be used to identify the best correctors and calculate the strengths needed to correct the errors. Since the success of the operation will depend on the accuracy of the as-built model, the primary objective of commissioning is to find an accurate model of the as-built beam line. [1]

Play-back and Real-time Applications

In general, the procedures to find the "as-built" model involve the following two-step procedure:

1. Measure specific beam parameters, and
2. Analyze the measured data.

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Development of Operator Thinking Model and Its Application to Nuclear Reactor Plant Operation System

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ABSTRACT

At first, this paper presents the developing method of an operator thinking model and the outline of the developed model. In next, it describes the nuclear reactor plant operation system which has been developed based on this model. Finally, it has been confirmed that the method described in this paper is very effective in order to construct expert systems which replace the reactor operator's role with AI (artificial intelligence) systems.

I. INTRODUCTION

A nuclear reactor plant has the following special features. How to control and operate it are the important subjects of research and development.

(1) Because it contains a lot of radioactive substances, it would harm public in case of the accidents. Therefor, its high safety is required.
(2) Because it gives society a great deal of economic loss in case of the stop of its operation, its high reliability is required.
(3) Because it is composed of many components which have different characteristics, its dynamic behavior is very complex.

In order to control and operate a nuclear reactor plant with such features adequately, the reactor operator's role is important and his burden is heavy specially in the case of the plant anomalous states. According to past serious accidents of a nuclear plant, it proved that mis-judgement or mis-operation is one of influential factors which would harm the safety and reliability of a nuclear reactor plant. Considering information processing characteristics of man and machine, the task allocation between both is decided as follows.

(1) Man is allotted to irregular tasks which require general judgement and decision making.
(2) Machine is done to regular tasks which require high speed processing.

In a current nuclear reactor plant, man takes the initiative of control and operation, and machine supports him. Therefor, various operator support systems are under development and some of them are applied to in-service real reactor plants.[1]

In order to improve further the reliability of a nuclear reactor plant, it is necessary to reduce occurrence probability of human error by replacing the reactor operator's role with the AI system. Such a plant called an autonomous one is under research and development. [2][3] In order to realize this plant, it is necessary to define a framework of the knowledge base and inference mechanisms of the AI system. One effective method would be to develop the operator thinking model and to utilize it. Based on this motivation, operator's thinking process and decision making process in the case of the plant anomalous states were studied using the full scope operator training simulator for "JOYO", the first experimental fast breeder reactor in Japan. In next, the operator thinking model was developed based on the experimental results. [4]

Still more, a nuclear reactor plant emergency operation system has been developed based on the above model. This system is an expert system which substitutes the operator's action to prevent a trip and maintain the safety of a plant in case of emergency.

II. DEVELOPMENT OF OPERATOR THINKING MODEL

At fist, the developing method of an operator thinking model is presented. In next, findings obtained by experiment and the developed thinking model are described in brief.

A. Method for Developing Operator Thinking Model

A.1 Experiment Condition

(1) Object plant : Experimental fast breeder reactor "JOYO"
(2) Simulator to be used : The "JOYO" full scope operator training simulator
(3) Experiment case

In order to attain our experiment purpose, malfunctions which satisfy the following conditions were selected.

1) They are able to be simulated by the "JOYO" training simulator.
2) They are so complex as an expert operator must think and judge.
3) They are not so complex as an expert operator cannot diagnose at all, for example, too multiple contingent malfunctions.

A.2 Simulator Experiment

The outline of typical experiment case is shown as follows.

(1) Object persons : One operator and one supervisor
(2) Selected malfunction
- Sodium leakage from the main primary B loop
- Failure that sodium leakage sensors do not operate
- Failure that sensors which detect the difference of rotation speed between A and B primary circulation pumps do not operate

A.3 Outline of Tasks for Development

Tasks for developing an operator thinking model are composed of the excusion of experiment and carried out after it.

Experimental arrangement around the training simulator is shown in Figure 1.

(1) Collection of data

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Operational Decoupling in the SSC Collider

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I. INTRODUCTION

This paper will summarize a recent study of the effects and correction of linear coupling in the Superconducting Super Collider (SSC) lattice. There are several aspects of the SSC lattice that make direct extrapolation of techniques used on existing machines unreliable. The most obvious aspect of the SSC which departs from previous experience is the small dynamic aperture which lies well within the beampipe. A second aspect is the existence of long arcs with low superperiodicity which allow various sources of skew quadrupole to accumulate to large, and, perhaps, nonlinear values. A third aspect is the relatively large value of systematic skew quadrupole error in the main dipoles. This results from asymmetric placement of the cold mass in the cryostat.

Coupling must be considered harmful if it leads to irreversible emittance blow-up, a decrease in the dynamic aperture, or inoperability of the machine. These negative effects are generally related to coupling terms that accumulate to large and, hence, nonlinear values prior to correction. The harmful effects can also be caused by the linearly coupled orbits interacting with high-order multipole fields that exist in the other magnets.

The errors that lead to linear coupling are well known. They are systematic and random skew quadrupole error fields in the other magnetic elements, angular alignment errors in the quadrupoles and feeddown from the sextupole fields associated with chromaticity correction, and persistent current fields in the dipoles. A study of the relative importance of the various coupling terms for a simplified SSC lattice is contained in Reference 1 (SSC-N-93 by Richard Talman).

The traditional way of correcting linear coupling is to use two families of skew quads and adjust them so that the separation between the two betatron tunes is minimized. This is a global scheme which is sensitive to only the betatron tunes which clearly are global quantities. Another traditional method is to focus on the sum and difference resonances and use two families to skew quads to correct them. Sometimes both methods are used, which requires four families of skew quads.

The method being proposed for the SSC is intrinsically different and amounts to decoupling one local section at a time. The mathematics required to do this are described in the next section. The primary motivation for local decoupling is that the errors are not allowed to accumulate and reach the level at which irreversible nonlinear mixing occurs. Local decoupling requires a measure of the local effect of the errors rather than the global effect of the errors. The quantity that goes directly into the decoupling calculations is simply the ratio of the out-of-plane tune amplitude to the in-plane tune amplitude. This quantity is directly measurable and has in fact been measured on the HERA proton ring and the Fermilab main ring.

Section 3 contains simulation results of the SSC collider with all known errors included and a full simulation of the correction process. It was found that 46 pairs of independently controlled skew quads are adequate to obtain a reasonably decoupled machine with a reasonable dynamic aperture. It was likewise determined that 16 pairs of skew quads are not sufficient to decouple the machine at injection optics. The minimum acceptable number and optimum placement of skew quads is a matter of continuing study.

*Operated by the Universities Research Association, Inc., for the U.S. Department of Energy under Contract No. DE-AC35-89ER40486.

A. Decoupling Formulation

The analytic formulation of the local decoupling algorithm is contained in Reference 2, Talman's discussion of single particle motion. A few of the key results will be repeated here for the sake of completeness.

The propagation of the four-dimensional phase-space vector X from point s_0 to s_1 is written in terms of the four-dimensional transfer matrix M shown below:

$$X_1 = M_{10}\, X_0 \quad . \tag{1}$$

The localized transfer matrix M_{10} may be written in terms of the once-around transfer matrixes M_1 and M_0 at locations s_1 and s_0, respectively. The relationship is given as

$$M_1 = M_{10}\, M_0\, \overline{M_{10}}\ , \tag{2}$$

where the bar indicates the symplectic inverse of the localized transfer matrix. The approach is to block diagonalize the once-around transfer matrixes at a sequence of points $s_0, s_1, \ldots, s_n$. The procedure necessary to block diagonalize each individual transfer matrix starts by breaking up the 4×4 matrix into four 2×2 matrices denoted by A, B, C, and D. One then forms linear combinations of the B and C submatrices responsible for coupling:

$$M = \begin{bmatrix} A & B \\ C & D \end{bmatrix} . \tag{3}$$

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Frequency Domain Analyses of Schottky Signals Using a VME Based Data Server and a Workstation Client

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Abstract

Schottky signals are extensively used for observation, setting-up and operation of CERN's Antiproton rings, namely the AC, the AA and LEAR. Measurement of these signals is, at present, carried out by a series of commercial instruments. These instruments have to be individually controlled and read by each application program. The operational use of the system is limited by the capabilities of the individual instruments. The first objective for the new system was to provide, as far as possible, a true "server". The "client" application program simply requests the data it requires. It is then supplied with measured and processed data. This provides the operator with a fast response by having ready processed data always available. Our second goal was to make the system operationally simple, with multiple windows and presentation on a single screen. This paper discusses some aspects of this implementation and applications for the antiproton production, collection, and storage rings.

INTRODUCTION

The system is to be used on the CERN Antiproton Collector(AC) and Antiproton Accumulator (AA) rings. The Antiprotons are first created by directing a 26 GeV proton beam onto a production target. The antiprotons are then captured, injected and stochastically cooled in the AC ring.

After cooling they are transferred to the AA ring where they are stored, and continuously cooled until needed by the physics programme. This is a multistep process involving rf bunch rotation and debunching, stochastic cooling in all three planes, rf recapture in the AC and bucket-to-bucket transfer to the AA, pre-cooling in the AA, rf capture in the AA and transfer to the stack-tail region and stack-tail cooling as well as core cooling for long-term storage in the AA. To have any yield at the end of this process, all the systems have to be set up to run with very high efficiency. In addition, due to the limited available cooling power, beam blow-up must be avoided at every step. Similarly, non-destructive beam diagnostic measurements have to be made, i.e. without disturbing and blowing up the beams. The technique chosen was spectrum analysis of the Schottky signals produced by the beams [1, 2]. By using appropriately positioned pickups and producing spectra of the revolution frequency sidebands, the beam profile in the horizontal, vertical, and longitudinal planes can be deduced. If the sensitivity of the system is known, the integral of the spectrum gives the beam intensity. At present, four types of spectrum analyzers, from two different manufacturers are used. Differences between these instruments leads to very complex measurement programming. To complement or replace these instruments, a very high speed, fast Fourier transform engine is needed. The VASP16 VME module from Computer General was chosen. This has a Texas Instruments 320C25 digital signal processor, and four Zoran vector processors on the board. The board is capable of performing a 1024 point FFT in 700 µs. The VME chassis is controlled by a Motorola MVME147 board running the OS9 operating system. The Motorola 68030 CPU transfers data from the ADC's (analogue to digital converters) to the VASP16 and services requests for data from the users. The ADC's are triggered to take data by the accelerator timing system.

OBJECTIVES

Replacing these instruments with a VME system, there are four main objectives.

a) To make the results available on request. At present each instrument has to be set up and then the measurement can be made. With the VME chassis data taking and processing can take place continuously, and the results presented on demand.

b) The spectrum analyzers have some real time constraints, they normally expect to acquire data, then process it, then display it. The VME system can acquire data at times fixed by the machine cycle, and fit in the processing between data acquisition.

c) The third objective is to separate the process of data acquisition from the task of presentation. This would allow any operator to access data without interfering with another operator's measurements.

d) This system has to be integrated into the control system. By using the VME system we can produce a standard interface to the control system, with all the specific low-level software hidden from the rest of the system.

SYSTEM OVERVIEW

Figure 1 shows a generalized overview of the system.

The resonant pickups consist of two parallel plates inside the vacuum chamber, one pair for the horizontal measurement, and a pair for the vertical measurement. The signals are brought out with vacuum feedthroughs and fed into a coaxial line resonator. The sum and difference signals are made using a hybrid and the resulting signals are amplified by low-noise amplifiers. The specific characteristics and needs for the respective rings are shown below.

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New Controls for the CERN-PS Hadron Injection Process using Operating Tools and High-Level Accelerator Modelling Programmes

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Abstract

A new control system using man-machine interface tools with workstations as consoles has been successfully put into operation for the injection of hadrons in the CERN Proton Synchrotron (PS). This paper mainly focuses on specialized modelling programmes involving complex treatments for an optimum operation of the injection process. These programmes include the control of the injection timings, the measurement of the beam emittance with an estimation of how well the incoming beam is matched, and the correction of oscillations at injection. The infrastructure and the programming environment underlaying the new control system are described elsewhere[3].

The outstanding feature of the internal structure of all these modelling programmes is that they carry out three kinds of data interaction: the input, that is the measurements (e.g. beam time positions, profiles and trajectories), the physical parameters (e.g. required times for synchronization, beam emittance, beam space position and angle at injection), and the output, mainly the hardware values (e.g. preset counter settings, currents to apply to injection steering magnets).

I Structure of High-Level Modelling Programmes

A control system provides the users with centralised access to hardware control values. These values can be obtained in various ways. They can be controlled individually, for example tuning a power supply current via a knob, or globally, setting all currents of a complete beam line from a selected file. In those two cases, the final hardware values are left to the user's appreciation. Their choice is made either following the effect on the beam, as in the first case, or at the time of the file selection, as in the second. Evaluation of these control values does not require implementation of the process involved in the control system.

However, in many cases the process involved is known and several control values can be worked out from the required machine and/or beam parameters. A dedicated programme can then be used to evaluate these control values from the user's requirements. Considering the previous example of a beam line, if the relationship between the power supply currents and the energy is known, setting a complete beam line for various energies does not require as many files as energies, but only one file and a dedicated programme working out the currents from the required energy.

This trivial example can be extended to more general cases. In the example of beam steering, the trajectory of the beam in a transfer line can be taken as input, physical parameters such as angle and position of the beam at a relevant position in the line can then be worked out from this trajectory, and finally current variations in deflecting elements can be computed to steer correctly the beam in the line. More generally, controls values (output) can be computed from physical parameters (parameters relevant to the process involved) which, in turn, can be computed from measurements on the beam (input). Modelling Programmes perform such operations and take care of computations between inputs, physical parameters and outputs.

In most cases, provided they are not too large, variations of beam characteristics (ΔX, inputs) lead to variations of physical parameters (ΔP) which can be expressed in a matrix formalism. The same applies to the variations of hardware control values (ΔY, outputs) which can be expressed from variations of the physical parameters:

$$[\Delta P] = [M_1] * [\Delta X] \qquad (1)$$

$$[\Delta Y] = [M_2] * [\Delta P] \qquad (2)$$

Modelling Programmes can compute hardware values from physical parameters or from beam measurements, using matrix M_1 or both M_1 and M_2. If matrix M_2 is not singular, one can also work out physical parameters by reading control values. This can of course be of great help for machine tuning. In the following section we present how these considerations have been applied to the timing process of hadron injection into the PS[1].

II Injection Timing Controls

In the injection process, timing pulses have to be delivered to various equipments in order to trigger them correctly with respect to the incoming beam. Preset counters are interconnected in such a way that they can provide the necessary pulses, with the proper time resolution, at appropriate instants with respect to external time references. One can then define the required times as physical parameters and the output as the control values to be loaded in the various counters. Looking at the timing lay-out, the required times

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CARSO - A Program For Automated First Turn Steering

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Abstract

CARSO is a program package which contains several new software tools to be used during first turn steering of a storage ring, or during the steering through a beam transfer line. CARSO includes routines which check the effects of magnetic components on the beam, check the measurements of the beam position monitors and simultaneously steer the beam through the ring to perform one full turn. The programs are written in ANSI extended standard FORTRAN 77 and comprise 6000 lines of source code, 87 subroutines and about 1000 different variables. The concepts used within CARSO are presented.

I. INTRODUCTION

The conventional approach to first turn steering is first to adjust manually some steering elements so that the beam reaches the last beam position monitor, and then to apply numerical orbit correction procedures to reduce the r.m.s of the orbit displacements measured at the beam position monitors [1,2]. During the manual phase the machine physicists often have to make some checks and reason about possible malfunctions of the equipment such as incorrect beam position measurements, quadrupole polarity errors, ineffective steerers, etc.

CARSO automizes the first phase and combines it effectively with the second. CARSO performs routine equipment checks systematically, notifies the operator when some possible errors have been found and tries to correct for some of them at their source. For the ones it can not correct, CARSO provides a fine adjustment of the beam towards the beam axis in a semiempirical way.

CARSO combines for the first time two concepts which itself are rather new for machine physics software. First, it actively uses the beam itself as a measuring device to test the components of the ring (a possibly similar approach is described in [3]). Before steering, first the relevant components are checked by sweeping the beam. Only if they behave as expected, they are used to adjust the beam towards the beam axis. The second concept is that rather than comparing the model of the storage ring with the measured beam positions globally, CARSO checks each monitor and the elements surrounding it separately (the same philosophy is applied in [4]). Thus it is able to localize gross errors rather precisely.

CARSO is capable of steering the beam successfully in spite of certain types of component malfunctioning, because it can recognize a few classes of error patterns and correct its model of the ring accordingly. CARSO still provides many interactive input/output messages and prompts, in order to give the human operator complete control over its performance. In this respect, CARSO can be viewed as an "apprentice" doing the simple and obvious routine tasks, reducing the load of the operator, who can thus concentrate on global reasoning.

CARSO uses machine theory as well as some heuristic experience of a skilled operator to evaluate the checks. If a problem is encountered that can not be solved by using this knowledge, CARSO informs the operator and waits for his/her intervention. Sometimes CARSO may "overlook" a severe error, but from its output the operator is nevertheless able to detect the error or to get at least some hints about the problem.

II. THE STRUCTURE OF CARSO

A. The Guidelines

The guidelines for the development of CARSO were:

- compare the predictions of the theoretical optics, which is represented by the model, with the measured beam position ;
- in case of a mismatch between the two, correct either directly the source of the error, correct the model, or at least minimize the effect of the error on the beam trajectory;
- make as little as possible assumptions, that can not be verified by a measurement - i.e. use the model only for comparison and not for calculations;
- avoid pure quantitative checks if qualitative ones can give reasonable answers, because there might be too many unexpected errors, degrading the numeric precision below acceptable levels;
- ensure that no action taken by CARSO sets the hardware beyond its limits;
- adjust algorithms to include heuristic rules of a human operator.

B. The Approach Chosen

For the purpose of first turn steering, when the beam traverses each element only once, a storage ring can be viewed as a simple beam transfer line. In a transfer line the basic approach is to adjust the elements so that the beam travels from one monitor to the next and so on, until the last monitor is reached. If the beam does not reach a monitor, it is obvious

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Control Protocol : The Proposed New CERN Standard Access Procedure to Accelerator Equipment. Status Report

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Abstract

Control protocol provides a normalized access procedure for equipment of the same kind from a control system. Modelisation and the subsequent identification of functionalities with their parameters, variables and attributes have now been carried out at CERN for representative families of devices.

ISO specifications, such as the ASN.1 metalanguage for data structure representation and MMS definitions and services have, to some extent, been introduced in the design for generality and compatibility with external world. The final product of this design is totally independent of the control systems and permits object oriented implementations in any controls frame. The present paper describes the different phases of the project with a short overview of the various implementations under development at CERN.

I. INTRODUCTION

Studies on protocols have been carried out at CERN for more than three years. The basic ideas have been set up in the frame of the Technical Board for Controls and Electronics (TEBOCO): this consultative Board had the mandate of investigating and proposing uniformisation and standardization in the concerned field.

The generalities of the control protocol and the results obtained with first prototypes implementations, have been presented at the Accelerator Control Conference in Vancouver, October 1989 [1] [2].

At the beginning of 1990, a working group called WOPRO (Working Group for Protocols, whose members are the Authors of this paper) was set up with the CERN Management mandate of studying and proposing control protocols for all accelerators at CERN.

Studies on Protocols have been carried out by WOPRO through two activities :

i) the different CERN equipments have been grouped in classes of similar devices. For each class, behavioural models have been proposed and the corresponding functionalities with the associated parameters have been identified. Appropriate structures for representing data have also been proposed. This activity, which is independent of the control system layout, has been carried out by the specialists of the WOPRO group.

II) the Control Protocol must be implemented in the actual CERN controls structures. This activity concerns more precisely all those services allowing the external visibility of the protocol, i.e.the access procedures to the equipment, and the software structures required by the protocol realisation. This implementation study is carried out by controls specialists together with the WOPRO members.

The first and main activity of WOPRO (conceptual design phase) has been terminated by mid 1991 [3] [4] [5] [6]. The second, implementation oriented phase, is under study and major results are expected for spring 1992.

II. MAIN CHARACTERISTICS OF THE CONTROL PROTOCOL

Standardization and uniformisation of equipment access is not a novelty in accelerator controls field. In fact the control system of each accelerator or Complex has introduced its own standard. What is different in the proposed WOPRO's approach, can be summarized in the following five points :

- The investigations have been carried out CERN wide. Each considered class of devices includes examples coming from the more concerned machines.
- The study has at first been bottom-up oriented, from the equipment to the control system. The proposed protocols fulfills then principally the needs of the users of the control systems at CERN.
- The functional description of the devices includes all aspects related to operation. In the accelerator field a device works very often in close connection with other equipment that is necessary for the accomplishment of its activity (triggering systems, function generators, etc.). The proposed protocols consider these equipment as part of the device and include them in the design.
- The design is based on behavioural models. For each family of the considered devices, the relevant specialists have firstly developed one or several behavioural models: the model includes all aspects that are necessary for an operational use of the device. This conceptualization has provided the degree of abstraction needed for the generality of the design.
- An object oriented approach has been used. The user has to specify "what" to do: the object-device knows "how" to do it. This allows a large independence between the implementations of the controls specialists and those of the device specialists. Other features of the object oriented design, such as class structures, inheritance, etc., are proposed in the implementation phase.

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Man-Machine Interface Workshop Summary*

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Abstract

This report is a summary of the Man-Machine Interface Workshop that took place on 14 November 1991 as part of the 1991 International Conference on Accelerator and Large Experimental Physics Control Systems in Tsukuba, Japan. The conference was sponsored by KEK, the Japanese High Energy Physics Laboratory.

I. INTRODUCTION

The topic of man-machine (MMI) interfaces has received much attention in the general computing literature, (see, e.g., [1]). The Man-Machine Interface workshop at this conference was motivated by desires to provide an interactive forum for the discussion of how current methods and new ideas can be used to make communications between the accelerator control systems and the control system users as effective and comprehensible as possible. The goals of this workshop were two-fold:

1) To identify unifying principles in the design and implementation of man-machine interfaces for accelerator/physics control systems;

2) And, looking to the future, to encourage discussion of new, possibly speculative, man-machine interface techniques and their application to such control systems.

The 1989 ICALEPCS conference in Vancouver included a workshop on the use of workstations in accelerator control systems. Part of that workshop dealt with the problems and possibilities presented by the use of workstations as man-machine interfaces in accelerator control system environments. It is interesting to compare the changes in emphasis that have become evident in two years. Comments from the 1989 workshop emphasized several aspects of the man-machine interface including: the need for realistic feedback for analog controls whether implemented through physics knobs or a window interface; the desirability of multiple, non-overlapping screens on each operator console; and the importance of tools for rapid prototyping.

As part of the 1991 MMI workshop, we hoped to encourage discussion of a wide variety of topics, including: display methodologies, interaction techniques, human- and software-related engineering concerns, user construction of interfaces, and speculative aspects of three dimensional presentation and virtual reality. In this year's session, we were particularly interested in learning about the current use of windowing systems and third party interface builders, and the construction and maintenance of interfaces by users.

II. PAPERS

The Man-Machine Interface Workshop at this conference featured four invited papers and a discussion period. The papers were selected based on the abstracts submitted to the conference program committee. The full papers are available elsewhere in these proceedings.

Kevin Cahill described the uses Fermilab has made of the X-Window environment for accelerator control consoles [2]. Fermilab is using DEC Vaxstations. A single keyboard/trackball and set of knobs is interfaced to multiple screens using a locally engineered interface box. The X-Windows environment has been exploited to allow remote consoles across long haul networks and to support multiple consoles on a single workstation. A Fermilab console was actually running on a Vaxstation at KEK during the conference. Read-only consoles and consoles with limited command capability help to allay feelings of unease among their operators. In addition, all commands are logged on a central server.

Frank Di Maio from CERN discussed the workstations that are being introduced as part of the rejuvenation of the CERN control systems [3]. The rejuvenation effort is based on Unix workstations with X-Windows, Motif, and TCP/IP communications. CERN's first attempts included console emulation for some of the NODAL-based applications. The workstation environment includes a user interface editor and an interactive application builder.

A completely new system based on Unix, X-11 and the PHIGS graphics standard was described by Franco Potepan of the ELETTRA Synchrotron Light Source in Trieste, Italy [4]. The ELETTRA system has a very natural interface that allows direct access and manipulation based on CAD-derived pictures of the entire accelerator complex. This interface was an attempt to continue the desktop metaphor in the accelerator environment.

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Summary of Panel Discussion on Standards and World-Wide Sharing of Software

Organizer: P. Lucas (Fermilab)

Participants: C. Briegel (Fermilab, P.Clout (Vista), D. Gurd (SSCL), N. Kanaya (KEK), U. Raich (CERN)

It has been a dream in the accelerator community for some time that software developed for one control system be easily transferrable to and usable at another. Until recently this goal was seldom realized in practice. This has been primarily because the various control systems have been developed in-house with little standardization among them. The world of accelerators was dominated until a few years ago by very large machines constructed for doing high energy physics. The large laboratories could likewise afford large controls groups, which were able to build these complete systems from the ground up. However the accelerator scene has now shifted, with a large fraction of the new work being done at much smaller installations, installations which cannot afford the large staffs previously employed in control system production. Different approaches to this problem were outlined by P. Clout: having one or more smaller laboratories follow in the footsteps of a larger one, use of industry standards to such an extent that a significant amount of software is transferrable, or purchase of control systems from commercial vendors.

This discussion centered on the second of the points mentioned - that use of standards could foster transferability. Standards are becoming very important in the world of distributed computing as they allow the equipment of various vendors to interoperate on an integrated network. Since most accelerator control systems utilize such networks, they are indeed in the process of adopting various various standards. Among those mentioned, which have achieved to a lesser or a greater extent penetration of the accelerator field, are the Unix operating system, the X11 windowing system, the Motif presentation layer, and the TCP/IP networking protocol residing primarily on Ethernet but also on Token Ring physical layers. Most controls hardware being constructed resides in VME and to a lesser extent Multibus II, with a large installed base of Camac and its attendant driver software. The Oracle product is becoming a *de facto* standard for off-line database work, but no clear one is emerging for real-time databases. Similarly there is no standard for a microcomputer operating system, but at least there are a few commercial products being utilized, as opposed to the do-it-yourself philosophy espoused in the past.

The consensus of the discussion was that at the level of workstation console applications the prospects for shared software were good. Use of X11 and Motif have already allowed portability of some graphics widgets, an activity which is expected to continue. At levels of control lower than that of operator interaction, the prognosis is not so good. Much of the low level software of any system revolves around the database, an area in which there is no standardization as to product used or even as to the nature of the data stored.

At a less involved and more practical level it was suggested that a computer bulletin board could be initiated on which control system problems and insights could be made available to the community.

It was also noted that for software to be shared effectively it must be documented well. Although there were differences of opinion on who could best document any software and on what sort of documentation was most appropriate, there were none on the blanket statement that this is an area in which we should all strive to do better.

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Panel Discussion on Management of Control Systems

Don Barton (BNL), Axel Daneels (CERN), Winfried Busse (HMI), Lindsay Coffman (SSCL & DOE), Shin-ichi Kurokawa (KEK), Rudolf Pose (JINR)

Reported by Axel Daneels (CERN)

I. INTRODUCTION

In scientific organizations one often encounters the opinion that management is a trivial activity and that project managers enjoy the easy side of the project life, far away from where the real work is. However, examples abound of projects failing to meet their objectives, running behind schedule, overrunning costs, etc., because of poor management. To several aspects which are crucial for the successful completion of a project the attention they deserve has to be paid if the project is to meet its objectives within the constraints that are imposed upon it. Whereas the engineers do things, the manager gets things done; managers are particularly concerned with:

- what is planned to be done: i.e. the product which should be delivered, in our case the control system,
- how long will the project take: i.e. schedule,
- how one will know when the project is finished: completion criteria,
- how much will it cost to implement and to maintain: i.e. the cost.

These issues can e.g. be classified in three categories respectively relating to:

- the project:
  analyse the requirements, define the quality that needs to be achieved, estimate the schedule, evaluate the cost, analyse the trade offs in order to decide e.g. whether it is preferable to phase out or to upgrade an existing system, whether one should build in house or buy commercial products, etc.,

- the logistics (hardware and software):
  what level of support should one expect during the life cycle of the project; how reliable should the system be; how maintainable; what level of safety should one reasonably expect; how much training will be requested so that the user can take up operating the new system himself, etc.,

- the technology:
  what standards should be used; are these standards likely to stay actual during the life cycle of the system; what techniques should be applied for the implementation, (e.g. computer aided software engineering - CASE -, other tools, use of advanced techniques,....); what products are available on the market that meet the requirements, etc.

II. INTRODUCING THE PANELISTS

The panelists who were invited to animate this session were selected not only on the basis of their experience in conducting control systems but also because they represent a variety of backgrounds and environments. Indeed, they all represent laboratories which are of different sizes and which operate in diverse economical and political conditions.

Each panelist introduces himself and describes briefly his current activities, the project he is concerned with, the size of the group involved in these activities and any possible "cultural" particularities of his environment that influence his activities.

- Don Barton (BNL/RHIC-AGS) heads a group of 11 program analysts, 8 electrical engineers and 9 technical support people. The group is in charge of the controls of both the Alternating Gradient Synchrotron (AGS) and the future Relativistic Heavy Ion Collider (RHIC). In addition to providing maintenance support for the running physics program at the AGS (for both protons and heavy ions) and for the commissioning of the new booster, the group soon will need to initiate the study of the RHIC controls. Besides the evolving technology, the biggest challenge stems from the sheer size of the entire accelerator complex, and consequently also of the control system. At present there are about 60 workstations and 80 to 90 multibus I crates with real time systems in a very distributed environment. The total effort invested so far is around 60 to 70 manyears.

- Winfried Busse (HMI/VICKSI) is responsible for the control system of the VICKSI facility. VICKSI is a comparatively small installation which was put into operation in 1978. Despite an upgrade program, started in 1987, the support the controls receive from the upper management of the laboratory is continuously decreasing. Originally 9 persons strong, the group is now limited to 3 people looking after the everyday running of the system and one person endorsing the entire upgrade program. It is thus no surprise that progress is very slow.

- Lindsay Coffman (SSCL & DOE) works on the DOE (Department of Energy) side of the SSC Laboratory. He is responsible for Systems Engineering across the SSC project. Coffman's office, currently 5 persons but intended to grow to 12, has to ensure that the SSC project follows the proper engineering practices: i.e. follows the modern systems engineering and management practices with discipline, adheres to current standards, follows state of the art software guidelines and development practices, delivers the proper requirement documents, etc.

- Axel Daneels (CERN/AT) involved in controls until 1990, was responsible for the development of the application software of CERN PS accelerator complex. Currently

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ISSUES in ACCELERATOR CONTROLS

A personal view, from a distance and in soft-focus

(Conference Summary, ICALEPCS-91)

Berend Kuiper, CERN, Geneva, Switzerland.

Dear colleagues,

The fact that I am standing here in front of you at this moment of the conference should issue two different signals. To you it should signal that the more frivolous part of the meeting has started; to me it signals that I must have reached a certain age....

The second personal comment which I want to make is that, at the lunch meeting in San Francisco, when the International Scientific Advisory Committee, ISAC, were discussing the ICALEPS-91 programme, my friend Shin-Ishi Kurokawa suggested that I should say the "closing words". Of course I was very flattered and, since that looked to me like an affair of ten minutes, I promptly accepted. By the time I received the final programme, two weeks ago, I found myself put down for a "conference summary" of 40 minutes. Of course I am still very much honoured and - noblesse oblige - I shall try ..... But what I shall really present to you, will be in the form of a, somewhat hand waving, overview of a number of main controls issues, as I think to see them, from a certain distance and in a soft-focus, with occasional side comments on what the conference gave. So it is neither of the two, or both, however you like to see it.

When attempting to make conference summaries of this kind, one is always tempted - and possibly even expected - to "discern" and then to point out the "great lines" of evolution of the subject and then to make predictions, "far sighted" if possible. Of course such an activity is jolly risky since at the beginning of any such trend, a few discernible examples and implementations of one sort, or a new product here and there, do not necessarily make a trend. By the time the developments have really taken on, however, the "great line of evolution" has become obvious to just about everyone and chances are that the trend is already approaching its end and that some other trend - at that point with hardly decodable patterns - is already infiltrating the old situation which - since it is by now known - has become comfortable and homely and - thank God - at long last more or less efficiently usable.

What, then, is there - other than the technical novelties themselves, which are so disconcertingly complex and changing - what is there to guide us in deciding our directions, to decide what course we shall choose, what we shall buy, etc. Well, ladies and gentlemen, it may sound like a platitude, but the sole constant factors in all this - on the long term - are, on the one hand, human nature with its penchant for comfort and simplicity in doing one's job and, on the other hand, the omnipresent limitations in our resources, in other words considerations of economy.

Now I am not trying to deny that some future technological breakthrough can bring an enormous benefit and change radically the way we think about our problems and that, in doing so, it may hit us from an ambush or so to speak pull the rug out under our feet. We have lived through that before. What I want to say is that this will only happen if that breakthrough brings convincingly more comfort and/or economy. Vendors are slowly learning to bring their new products and trends in a more constructive way and not any more with the sole aim of wiping out the competition and thereby possibly also the very customers they are trying to court. The reasons for this - recently more rational - behaviour is human nature and economy. The human wish for comfort blows up the software packages - systems and applications (just think of transmission protocols, graphics, etc.). The investments are then becoming so enormous that frequently learning new systems and porting software become insurmountable barriers. And creating new such barriers becomes increasingly unpopular with the clientele, who are constantly growing and, through user groups and other