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OPERATING EXPERIENCE WITH THE VICKSI COMPUTER CONTROL SYSTEM

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Summary

The VICKSI control system is based upon a standardized hardware and software design which is reflected in a minimal design effort and in a maximum utilization of similar components which make it easy to maintain. The system is designed in such a way that knowledge of computers and programming is not a prerequisit for the operational user. The operator consoles use touch panels for parameter, program and option selection in normal man-machine interaction. The implementation of an interpreter with full access to the process parameter values in engineering units by their physical names facilitates programming for the machine physicist.

The performance of the system as a control system depends primarily upon the reliability of the hardware, upon the quality of programs available and upon the flexibility and yet simplicity of the man-machine interface. The present state allows full control and monitoring of the complete accelerator system. Hardware weaknesses have so far only shown up in the analogue acquisition system. All known software bugs have been eliminated. The system is in a stable and reliable state and is used as a convenient tool for accelerator operation. It is flexible enough to allow future extensions.

Introduction

The goal of the HMI VICKSI project was the commissioning of a new separated sector isochronous cyclotron using the existing 6 MV single stage van de Graaff as an injector. A detailed description of the features, the lay-out and the performance of this accelerator facility has been given earlier[1][2][3][4]. Design, construction, assembly and running in covered five years since late 1972. Experiments were started in early 1978. The present status is given in a separate contribution to this conference[5].

Along with the approval for the accelerator system as a heavy ion facility, it was decided to install computer assisted control. It had to be available at a rather early state for component testing and commissioning of accelerator and beam line equipment.

As the conceptual design of the control system has been detailed earlier[6][7], only some essentials of the hardware and software layout will be given here.

Control System Layout

General remarks

As the whole project was given a hard manpower and time constraint, the first goal of the VICKSI control system design was to set up a system which allowed setting, logging and monitoring of all accelerator parameters. The accelerator subsystems were to be designed to be stable and reproducible to a very high degree in such a way that closed loop control was not a primary requirement. Hardware safety was to be done by hardwired interlocks and beam observations were planned to be done by multiplexed meter connections, i.e. no time critical reaction of the computer system was demanded.

Although automatic start up or closed loop control was not a primary goal, it was decided that all the available status information, parameter monitoring and control were to be implemented to make it available at a later state.

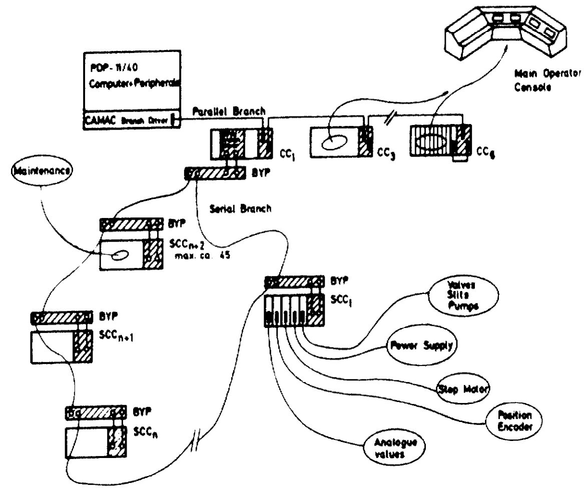

Fig. 1: Schematic view of the control system hardware arrangement.- All interaction devices (e. g. control knobs, touch panels, etc.) are hooked to the parallel CAMAC branch. Process equipment is connected to modules which are installed in the serial CAMAC loop. Amongst other things bypass units provide isolation between crates. Isolation between devices which are hooked to the same crate is not provided in the modules but rather at the device port.

Hardware

A schematic view of the VICKSI control system is given in fig. 1.

A PDP-11/40 with 124 K of core memory and the necessary mass storage is used as the control computer.

The Operator Main Console is interfaced to the computer over a Parallel CAMAC Highway allowing fast interrupt handling and data transfer to the various operator interfaces.
The console consists of several general purpose control bays with only a few interaction devices such as touch panels, control knobs and colour displays[8]. Two bays contain dedicated devices for the van de Graaff and beam current observations.

The accelerator and beam line equipment is interfaced to the computer via a Serial CAMAC System, operated in byte serial mode at 2.5 M bytes/sec[9][10]. It follows the beam lines and

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covers a distance of about 350m driving a total of 50 CAMAC crates. BYPASS units (U-port Adapters) provide signal refresh, isolation between crates and a relay bypass for faulty BYPASS/CRATE combinations. The relay bypass may be activated by the computer to facilitate program controlled fault tracking. The drivers for the serial system are operated from a crate on the parallel branch.

The control and monitoring modules[11] which interface the accelerator equipment to the CAMAC system were specified to be as robust as the CAMAC specifications would allow and to contain only those functions that are really required by the control system philosophy. For the specification we have chosen an equipment oriented approach which combines all necessary functions into one module to handle one particular type of equipment. Apart from the analogue acquisition system, only 5 different module types were necessary to interface all the equipment.

CAMAC test modules and appropriate test programs for each interface module type simplify pre-installation testing as well as trouble shooting during operation. Sufficient spare modules have been provided to cover quick replacement in case of a failure as well as the repair time needed by the electronics work shop.

Module similation boxes assure off-line testing of the accelerator equipment especially in areas where local control was not implemented.

Software

The software is based on table driven subroutine packages which are held in shareable libraries for use by the control system operating software, by any type of application program as well as by the MUMTI interpreter which we implemented as part of the man-machine interface.

The physical values and engineering units of accelerator parameters are accessible by their unique symbolic names to any control system task including the interpreter which can use these so-called SYSTEM VARIABLES as any other program variable. Control and acquisition of a given parameter results in WRITING and READING to and from a System Variable respectively. To achieve this, we have aggregated all the relevant specifications of a parameter into a DATA BASE. This concept facilitates the implementation of device independent routines and application programs because device dependent differences appear as corresponding information held in the data base rather than program logic.

The MUMTI interpreter for the VICKSI control system implements many features known from other control systems[13]. However, it was the first interpreter written as an incremental compiler whilst retaining all the advantages of an interpreter. The System Variables were implemented as variable type thus allowing complex process interpretation and control by simply writing down the corresponding formulas. Indirect and immediate mode command lines allow delayed or immediate execution. The addition of a command (HOOK statement) for periodical execution of parts of a program enables a single user to interact with the process in a multi-user, timeshared way.

The application program packages which are presently available allow full control and monitoring of the accelerator and beam line system. Service packages for control system internal use allow the management of all the necessary backup files, e. g. data base, error message, status text and touch panel files. Entries can easily be added , changed, deleted, listed or searched for elements with user selected attributes.

Experience with the system

Reliability

The computer system was delivered in early 1974. Until mid 1976 it was mainly used for hardware tests, program development, and a first test run for accelerator components in a realistic environment. During this time the system suffered from the dirty construction environment and the many moves from one site to another.

In April '76 the site became ready to start final installations and first test runs of the control system software. Test runs of the van de Graaff and injection beam line have been scheduled since early 1977. Normal operation periods for experiments have been scheduled since early 1978.

The control system down-time of 8-19% reported for scheduled test runs in 1977 was mainly due to software bugs and the consequent time intently taken for their analysis. The overall down time of the control system went down to 1 % in November 1977. This is also the magnitude of the down time of the accelerator due to control system failures since early 1978.

The control hardware interface was found to be extremely reliable ever since it had been installed. This may be due to the extensive burn in tests that we undertook at the moment when it was delivered. In addition we keep enough spares of every type of control equipment for quick exchange of faulty devices.

Unfortunately we have to state that the analogue acquisition system (relay multiplexers) is our main point of trouble. The meantime between failures is so small that we are presently looking for another system to replace it.

Performance

The performance of the control system is evaluated by the operator with respect to his interaction with the process through the man-machine interface. However, systems personel judge it by its flexibility with regard to hardware and software extension or its maintainability.

The concept of completely general-purpose control bays with only a few interaction devices, an idea which we copied from other control systems[14][15], was readily accepted. There was, however, an initial insistance upon permanent displays for various subsystems. We did not have the time to implement these displays and we hope that the general surveillance programs will overcome the need for them. As the beam observation equipment is "hardwired" (although multiplexed) to the beam current sources, the overall response of the system is felt to be sufficient.

Another operator interface which we implemented is the MUMTI interpreter. Whilst the consoles offer standard interaction with the process, the operator may feel free to program any kind of acquisition, control, monitoring or closed loop control by using the interpreter command language. The fact that accelerator parameters have been implemented as variables makes programming of correlations extremely easy. Machine physicists and engineers have welcomed this additional means of interaction. Setting up of the beam lines and optimisation of the cyclotron setting are generally done by MUMTI programs[16]. Although closed loop control was not a primary goal of the first phase installation, we now have a hybrid system with well-stabilized parameters combined with devices to measure beam properties by intercepting and non intercepting techniques. From the experimental results, corrected settings may be calculated and executed. Without the implementation of the interpreter, the running in of the machine would not have been possible given the limited man power and time schedule.

The extension of the accelerator system is easily done by the use of maintenance software packages for corresponding back up data files and tables. These programs were implemented right from the beginning. Many features have been added in the last two years, such as multiplication of standard device entries, change actions on multiple device entries, etc.

New Features

Alarm System

As has been pointed out in earlier reports[17], we have implemented for each part of accelerator equipment a so-called READY-bit which is in fact an additional status bit to be true if the device has entered a status needed for beam acceleration, transport or observation. This READY-bit can be tested by a special CAMAC test function without data transfer.

It follows that the READY state of the accelerator system is tested by observing these bits. A status word of a piece of equipment need only be read if the READY bit is not true. Although the whole accelerator system comprises more than one thousand single devices, there is a certain hierarchy or tree wise interconnection of these READY bits because of the hardware safety interlock. It came out that only 20 to 30 bits need constant polling (depending on the beam line system to the specific target area). If one of these bits is false there is a certain tree of further bits to be tested which finally leads to the faulty subsystem or device. In most cases this scheme apparently reduces the amount of error messages to be published on a failure.

The overall status information is aggregated in two lines and constantly displayed on the colour monitors of the general purpose consoles. These two lines represent the status of the whole system from the ion source down to the target area.

The present system does not yet include the check of the settings to be compared to the correlated readback values mainly because the analogue acquisition system is not reliable enough as stated previously.

Virtual System Variables

Virtual System Variables do not represent a parameter of a piece of accelerator equipment but a virtual device or a physical parameter. With the help of a virtual quadrupole, the operator may vary the focussing strength of a part of the beam line by coupling two or more quadrupoles. Beam alignment can often be achieved in a simpler way by coupling the steering elements which are involved. Physical parameters are, for example, the phase and amplitude of the 1st harmonic field contribution of the harmonic coils in the cyclotron. The Virtual System Variables are defined by a given correlation equation for the setting or reading of a corresponding set of normal System Variables.

We are implementing these variables by generalizing the System Variable handling routines in such a way that they may have other System Variables as parameters instead of constant numerical values. The control words of the data base entries are extended to distinguish between system variable names and numerical values.

Future Development

Additional Operator Consoles

The VICKSI control room had to be set up at the place of the original van de Graaff control room, i.e. there was only space for a console with 7 bays. Hence the control room tends to be very crowded especially at accelerator start up times or if the ligning up of the beam to the experimental area needs additional help of the experimentalists. Therefore, we shall add another general purpose console in the neighbourhood of the main console to be mainly used by the service personel. A third console will be mounted in the experimentalists' counting room. This console will only allow access to the parameters of the experimental areas cf. fig. 2).

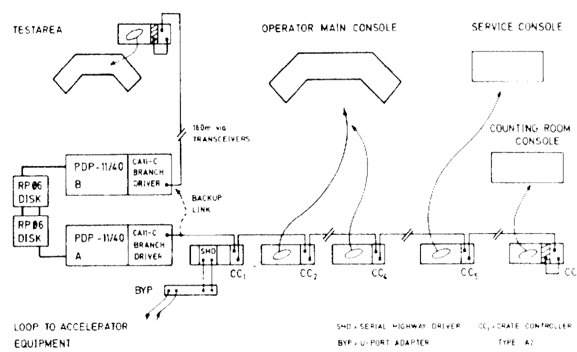

Fig. 2: Schematic view of the computer and operator console arrangement. - Computer A is the control system computer, B is used for software development as well as hardware testing. It serves as a back up computer in case A fails. Change over to the back up computer is done by switching the CAMAC branch from A to B and by interchanging the access to the RP06 drives.

Although it was felt in the beginning that there would be some need for a general purpose mobile console, we did not put much effort into its implementation mainly because the manual simulators proved to be sufficient for testing and maintenance. Experience revealed, however, that there would be considerable help in subsystem testing and fault tracking if one had a general purpose console available. It is felt that this console should generally offer the same facilities as the main console in the service areas.

PDP-11 CPU Exchange

With the extension of tasks to be handled by the computer we obviously run out of memory as the addressing capability of our PDP-11/40 ends at 124 K. As there is still enough CPU time available, we simply intend to replace the present CPU by one of the same family but with larger address range. By this exchange we could stay with the same operating system. The change over would not require any control system software change.

Microprocessors

We have already started to implement microprocessors at the crate level for very dedicated applications (time critical data acquisition) and we shall continue to do so where operations should be recycled constantly, e.g. in surveillance programs. It must be noted, however, that software development for such an addition is not negligible if the microprocessor must be programmed with low level code. Although we were lucky to find cross-assembler software for our application allowing PDP-11 code to be used for the microprocessor, we look forward to further development in the LSI 11 field which will allow the use of the same operating system in the micro as is used in the mini-computers.

Acknowledgement

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