THE COMPUTER AIDED CONTROL SYSTEM OF THE VICKSI ACCELERATOR

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Summary

The VICKSI control system is based on a standard-ized hardware and software design which is reflected in a central data base holding the necessary informa-tion for man-machine communication. This concept allows control and acquisition of accelerator para-meters by their physical names and values. As a con-sequence application programs need only handle their specific problem. Man-machine interaction is achieved on this basis via the main control desk or a specifically adapted interpreter which, in addition, is a powerful tool for machine study, trouble shooting or any non-standard operation.

The control system is designed in such a way that knowledge of computers and programming is not a pre-requisite for the normal user of the system. 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 parameters by their physical names and values in engineering units facili-tates programming for the machine physicist.

Introduction

The goal of the HMI VICKSI project[1] was the com-missioning of a new separated sector isochronous cyclo-tron 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 is given in another contribution to this conference.[2] Design, construction, assembly and running in covered five years since late 1972.

At a rather early stage it was recognized that the number of controls necessary for VICKSI was too large to be easily done manually. Therefore it was decided to install a computer assisted control system with the additional requirement that it should be available for component testing and commissioning of accelerator and beam line equipment with the in-direct effect of building up confidence and experience in computer control.

As manpower was a major problem within the project, it was generally agreed that we insist on strict stan-dardization of hardware as well as software which, in turn, would impose special requirements on equipment manufacturers. As a consequence the specifications for the control system had to be frozen in early 1974.[3]

Prior to our final decision on the control system design and configuration we studied existing systems in European and North American accelerator laboratories. We could extract positive and highly efficient tech-niques from their design and operating experience for introduction into our system after duly reducing size and facilities to our requirements. Thus we were able to have 90% of the control system hardware available by early 1975. The hardware tests and burn in were done using the first version of the operating system.

A short beam line section with new components was tested with beam in a realistic environment under computer control in late 1975.

Since then the continuing requirement for the control system has been, of course, to ensure regular operation for accelerator setting up, running in, beam development, machine study and finally the regu-lar accelerator operation for experiments. Neverthe-less it had to provide sufficient flexibility to meet changing requirements.

As the conceptual design of our control system has been detailed in earlier publications,[4,5] I shall now only give some essentials of the hardware and software lay-out to facilitate the understanding of the information flow and performance during operation.

Hardware

The basic aim of the control system is to enable the operator to perform the following simple opera-tions in a convenient and reliable way with the help of the computer:

- Data Acquisition   (READ parameter values)
                      (READ status information)
- Data Command   (WRITE/SET parameters)
                      (EXECUTE a status change).

Thus, the power of the computer is to a large extent used for multiplexing digital information between the control room and accelerator components.
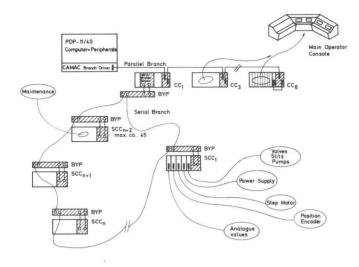
To simplify hardware interfacing and to reduce software complexity, we decided to establish a defi-nite set of design standards (hardware and software) prescribing functional lay-out, fabrication and list of components or subsystems to be used in the design of equipment, as has been common practice in instal-lations of control systems of other new accelerators.[6] This leads to a system with minimum duplication of design effort, with maximum utilization of similar components, and with a uniformity that will make it easy to maintain. In addition the large number of similar components would reduce the production price and facilitate a purchase order to commercial manu-facturers. Therefore we either tried to find adequate equipment on the commercial market or to commercialize required components by tendering bids after due specifi-cation of these required components.

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

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

The Operator Main Consoles are interfaced to the computer over a Parallel CAMAC Highway.[7] The distance between console and computer to be covered by the parallel highway is small, and we profit from fast interrupt handling and data transfer to the various man-machine interfaces of the Main Console.

The accelerator and beam line equipment is inter-faced to the computer via two Byte-Serial CAMAC[8] loops which cover a distance of about 350 m and drive a total of 50 CAMAC crates which are distributed almost equally along the beam line system. The BYPASS units

Fig. 1: *Schematic View of the VICKSI Control System Hardware*

Fig. 2: *The variable IQUAE1 represents the current of the 1st Quadrupole in beam line section E*

installed with each crate allow for bypassing a powered down or faulty serial crate system as well as for clock and data signal refreshing. The transformer decoupling between BYPASS units provides a galvanic isolation between crates. The lay-out of the serial system[9] is such as to allow an operating speed of 2.5 M Bytes/sec at a maximum distance of about 90 m between BYPASS units. The drivers for the serial loops are operated from the parallel branch as this type of driver was the only one available at the time when we decided to use Serial CAMAC.[3]

The control and monitoring modules which finally interface the great variety of accelerator equipment to the CAMAC system were specified according to the above mentioned requirements in such a way as to minimize the number of different module types (7 in our system). For the specification we have chosen the equipment oriented approach which combines all necessary functions into one module to handle one particular type of equipment. This approach has the advantage of a single cable between the module and the equipment, but obviously requires stringent standardization of the equipment. Having analyzed the necessary equipment control parts, we found that the modules to be specified are still general purpose modules and they are now commercially available as catalogue items from CAMAC industry.

A further advantage of this equipment oriented or, better, problem oriented approach is in the area of maintenance and trouble shooting. For each type of interface there is a test module which allows on-line computer testing of these interface modules as well as a module simulator which provides for off-line testing of the accelerator equipment at the computer control port, which is important for equipment without local controls.

Software

The basic requirement for the software is, most generally speaking, the detection of an attention request and its interpretation according to pre-established rules.

It is common practice to identify pieces of equipment by a unique name to simplify remote communication. Similarly giving accelerator parameters a unique name which is a mnemonic of the type of
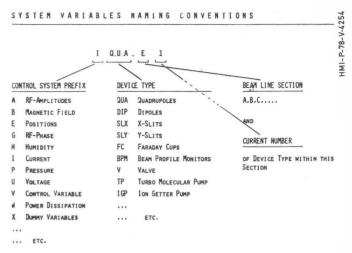
equipment, its position and function would apparently simplify man-machine communication (cf. fig. 2). The basic operations would then be the control or acquisition of parameters which are identified by a unique name, using their physical values and engineering units. The software would have to translate the names into the address of the corresponding interfacing module and to convert the physical values into appropriate register contents or vice versa according to the required function.

To achieve this we have adapted the data bank feature[11][12] known from other control systems[13] by aggregating all the relevant specifications (e.g. hardware, CAMAC interface, acquisition or control values, engineering units, name of conversion routines) about these parameters into a Data Base. Once this information has been entered into the Data Base the user need only concern himself with the name of that parameter, which we call a System Variable of the control system.

Control and acquisition of a given parameter will then result in WRITING and READING to and from a System Variable, respectively, i.e. application programs will simply call one interface routine for all control and acquisition operations for a given parameter. This routine handles all the necessary Data Base operations and will induce the appropriate action.

Keeping this in mind and going back to the schematic view of the VICKSI control system (fig. 1) will clarify the following summary of our basic software packages:

Resident CAMAC Library:

- CAMAC Interface subroutine which operates all CAMAC transfers and which is transparent to the user (calling program) whether a crate is installed on the parallel branch or in any of the serial loops. Crate addresses may range from 1 to 62; they must be unique.

- CAMAC interrupt service routines

- Crate status tables including initialization status and installation position

Resident SYSVAR Library:

- Data Base and process-to-System-Variable interface routine. It searches the Data Base, testing whether a given name is a System Variable; if yes, it determines whether type and direction (WRITE/READ) are permitted combinations and will on

READ acquire the appropriate CAMAC register, pass control to the conversion routine given in the Data Base and finally output the "acquired physical value" and on

WRITE pass control to the appropriate equipment driving routine which converts the physical input to CAMAC register output and initiates the CAMAC transfer.

- Equipment driving routines, which reflect the type of equipment and the type of interface module, if this applies.

Based on these libraries, application programs may handle all the necessary input and output operations using parameter names and engineering units to handle their specific problem.

The application program packages which are presently available allow full control and monitoring of the accelerator and beam line system through the existing man-machine interface. Service packages for control system internal use allow the management of all the necessary back up files, i.e. data base, error message file, status text files, touch panel file, etc. Entries can be easily added, changed, deleted, listed or otherwise manipulated in ways experience shows to be useful.

Man-Machine Communication

We have implemented two ways of man-machine communication for the VICKSI control system. The first way uses operator consoles relying on the program

packages which are available within the system, the second is by the use of our MUMTI interpreter.[17] Their design was adapted almost completely from the CERNLab 11 solutions.[14,15,16]

Main Control Desk

A view of the Main Control Desk is given in fig. 3 and 4. Each bay has only a few standard devices such as touch-panels, knobs, keyboard, colour and BW-TV monitors for interaction with the system.

The touch panels[18] consist of a BW-TV monitor under a transparent screen with 16 touch sensitive areas for parameter selection, program request, program-option selection, device-to-knob assignments or

Fig. 3: Photo of the VICKSI main control room

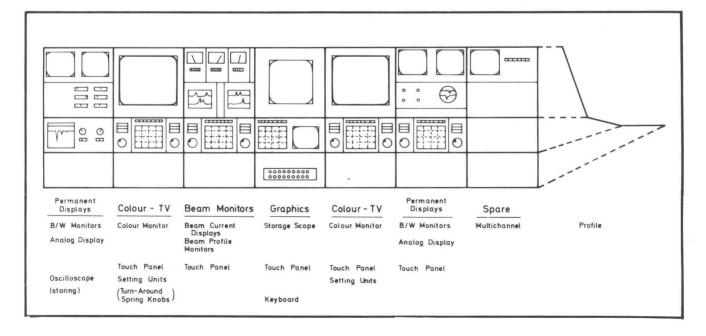| Permanent Displays	Colour – TV	Beam Monitors	Graphics	Colour – TV	Permanent Displays	Spare	
B/W Monitors	Colour Monitor	Beam Current Displays	Storage Scope	Colour Monitor	B/W Monitors	Multichannel	Profile
Analog Display		Beam Profile Monitors			Analog Display		
Oscilloscope (storing)	Touch Panel Setting Units (Turn-Around Spring Knobs)	Touch Panel	Touch Panel Keyboard	Touch Panel Setting Units	Touch Panel		

Fig 4: Schematic View of the Main Control Console

device-to-display assignments. Seven hardware push buttons arranged above the TV screen are assigned fixed operational functions such as "Return to Home Page," "Step Forward/Backward one Page on Same Level," "Quit and Clear Error Messages." Touching a button on the screen would normally "Step Down one Level" in this scheme if 'page turning' was the control assigned to this button.

The knobs[18] are provided for the variation of control variables once the assignment has been made. Their alpha-numeric display areas display the parameter name, the present setting value and the value of a corresponding acquisition variable including its engineering units.

The control console represents in its own a multi-user "parallel access" man-machine interface. Whilst the general purpose bays contain a touch panel, two knobs and a colour TV screen for general process control and interaction, other bays contain dedicated equipment for special purpose, such as a graphics screen, BW-TV monitors for permanent displays of critical accelerator parameters, analogue meters and oscilloscopes for beam diagnostics.

An operator who has had no previous computer experience can, after a minimum of training, select parameters and adjust these in a manner which is very similar to the classical "one parameter-one knob" control system. When an operator wants to change a parameter, he may do this by selecting it with the help of the touch panel. Fig. 5 gives an illustration of this procedure. The operator could start by selecting the so-called "Home Page" which gives the different subsystems of the machine such as 'Ion Source,' 'Van de Graaff,' 'Injection Beam Line,' 'Cyclotron,' etc. or parameter grouping by type of equipment such as 'Vacuum,' 'Quadrupoles,' 'Dipoles,' 'Beam Diagnostic.' Say, the operator selects 'Injection Beam Line.' The computer will then turn to the page giving a choice of the section within that beam line and other options. If the operator selects 'Beam Optic of Section G' he will find himself in front of a "parameter page" giving the elements available in that section. Selecting 'QUAG2,' i.e. the 2nd quadrupole in section G will then turn to the 'Option Page' for this device, offering to the operator the choice of options he may select for this parameter such as

- Switch ON/OFF;
- Display STATUS on touch panel giving the text for each bit labeling 'N' (O) those conditions which are not true;
- Display current IQUAG2 on the corresponding colour TV
- SET new value by turning to a digit page and entering a new setting by touching the corresponding digit buttons;
- HOOK the parameter to LEFT/RIGHT KNOB for setting variations.

As long as a parameter is hooked to a knob, the corresponding acquisition variable display is continuously updated from the process to enable the operator to follow the process reaction to setting variations.

The usage of the general purpose colour TV screens is explained by fig. 6. The upper third is assigned to a fixed purpose, such as display of experiment and date, display of specific error messages at the moment when a faulty condition is observed by a surveillance program, and continuous Status Display of the beam transport system down to the preselected target area, where upper case letters represent whole subsystems

whilst lower case symbols stand for pieces of equipment which may enter the beam path such as valves and Faraday cups. Green symbols represent a beam path ready for beam transport. They turn red on failures and interlock conditions becoming true. Presently only hardware conditions are continuously checked, displaying the result by updating this Status Display.
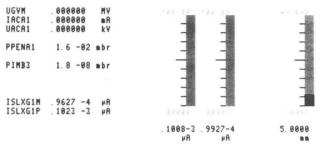

Fig. 6: Example of a colour TV parameter and overall status display

The lower part of the screen is used for acquisition parameter displays (bar or digital representation). The operator is free to compose a display of his choice, to save this display or restore a former one. All parameters appearing in this part of the screen are continuously updated from the process at a parameter dependent rate.

MUMTI Interpreter

Having learnt from the CERN SPS system that the early availability of an interpreter is a tremendous help for hardware testing, running in and machine study, we have undertaken the effort to implement a powerful interpreter having full access to the process by its unique parameter names which we called System Variables.

MUMTI program variables must either by System Variables (which is automatically checked first), in which case their type is implicitly known to the interpreter via the data base entry, or they must be declared (INT, REAL or STRING).

The following are some MUMTI properties which should be emphasized:

- 3 integer formats (binary, octal, decimal)
- logical and shift operators
- powerful IF-statement
- indirect and immediate mode command lines
- periodical execution of parts of the program (HOOK-statement)
- compile command
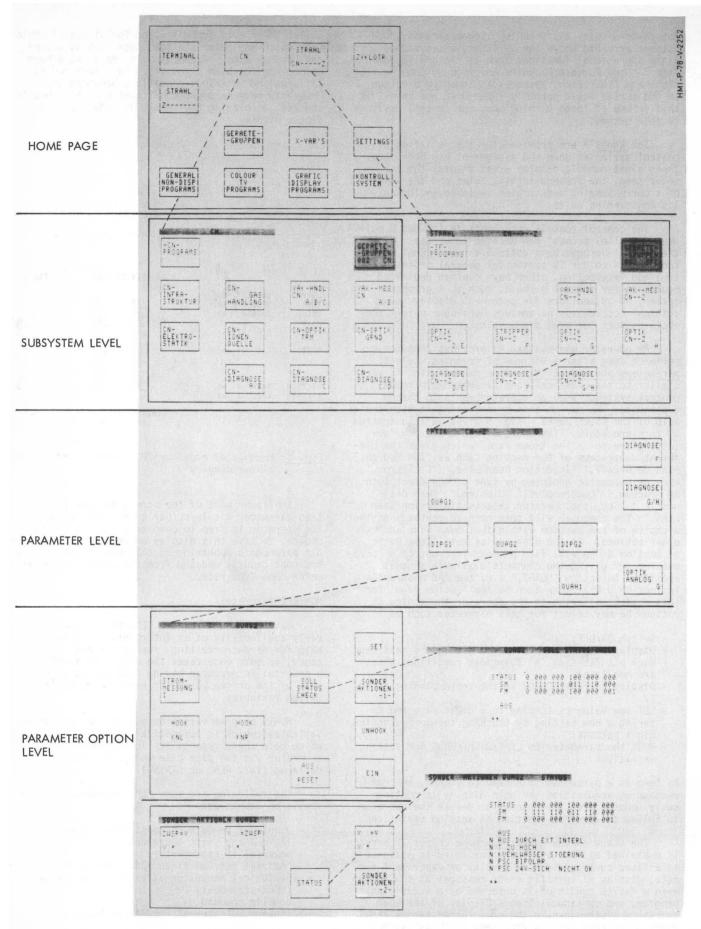- linkage to external FORTRAN or MACRO subroutines

Fig. 5: Illustration of the parameter selection via touch panel

The interpretive mode of working through MUMTI makes work much quicker and more satisfying. Programs can be adapted to new requirements and immediate commands are invaluable when something goes wrong and the normal programs are not suitable.

Performance

The performance of the system as a control system depends primarily on the quality of programs available. The present state allows full control and monitoring of the whole accelerator system. Hardware weaknesses have so far only shown up in the analogue acquisition system. Software bugs have been eliminated as far as they are known. The system appears to be in a rather stable and reliable state.

Higher level application programs, e.g., to automatically line up the beam or center it in the cyclotron, have been written in MUMTI by the machine physicists who were responsible for that particular part of the system.

Presently the lack of more sophisticated surveillance programs is felt to be a bottle neck in operation.

Conclusion

The VICKSI control system has proved to be acceptable in its flexibility and ease of programming. It is a reliable and convenient tool with which an operator can run the accelerator system without having to study computers, operating systems and sophisticated programming.

The standardized hardware and software approach facilitates the design and implementation of more sophisticated programs for beam development, machine study, logging, alarm and maintenance. Our next step will be to introduce Virtual Variables which readily describe a physical problem but which are functions of System Variables. This should help beam development considerably.

We are encouraged in our approach to this control system by the fact that other new control systems are being developed along similar lines.[19,20]

Acknowledgement

The work reported here is the result of many fruitful discussions with colleagues of HMI and other laboratories, especially at CERN.

The hardware interface was designed in collaboration with the HMI Electronics and Data Division, who also developed the MUMTI interpreter. We gratefully acknowledge their contribution. The implementation of the VICKSI control system would not have been possible without the effort and personal engagement of my colleagues from the control system group: H. Kluge, T. Kiehne, I. Krekow, Ch. Stahl and M. Stanek.

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** DISCUSSION **

H. SCHREUDER: How many man-years have been invested in the software?

W. BUSSE: Up to now we have invested 14 man-years—excluding the interpreter, which needed 6 man-years for the language part of it.