PROPOSED FULL AUTOMATIC CONTROL SYSTEM FOR THE MEDICAL SMALL CYCLOTRON C-30 AT THE INSTITUTE OF NUCLEAR STUDIES, POLAND

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Summary

The computer control system for the C-30 Medical Small Cyclotron, which is currently under construction at the Institute of Nuclear Studies will be presented.

The features of this simple and secure system are briefly discussed. Some efforts have been done to make a conversational system easily understendable for operators.

The keystone of the control system is an fibre optical link (wireless) between the cyclotron and the computer. The control system is based on the use of an extended configuration of the IBM PC/AT computer. A new system software is used to execute multitask hierarchical programs to control the cyclotron. The comercial adapters for control and data aquisition, connected with the fibre optic communication channels are used to transmit data and control codes.

Two colour graphic CRT displays the ongoing status and function of each controlled units so that the operator can monitor the whole system conditions at a glance.

The paper gives a general description of the programs which are executed on the computer. It also shows how the cyclotron is controlled by dedicated computer practically without special electronic equipment except of the hardware safety cutout switch.

The cyclotron is protected against operating incidents and mistakes by a complex system of interlocks.

Introduction

The C-30 cyclotrons will be installed and operated directly in hospital buildings thus their operation must require no technical personnel. All operating procedures should be performed by personnel using the cyclotron beam after only necessary training. Starting the cyclotron will involve only turning on the power supply, turning on the computer and entering from the keyboard required beam data. After some time, necessary for the vacuum to reach the required level in the cyclotron chamber, electrical and thermal stabilisation of the acceleration voltage generator (RF) and the main magnet power supply circuit as well as to turn on the source and to start the beam emission, the control system will print a message that the cyclotron is ready for operation and will give pertaining beam data. The switching on and off of the cyclotron and its operation control will be performed by a programmed computer. Diagrams of particular cyclotron installations (magnetic field, RF, ion source, vacuum, cooling) will be shown on TVC monitors and data gauged printed at appropriate points of the diagrams and updated at fixed intervals.

The idea of automatic operation and control evolved after the analysis of material avaiable on the systems of cyclotron control[4,7] on the basis of my experience with operation of JINR cyclotrons in Dubna (U-200, U-300, U-400) as well as literature, particularly proceedings of the IX-th and X-th Conferences on Cyclotrons in Caen and East Lansing.

The Concept of a Cyclotron Control System

In cyclotrons built or modernised at present[1,2] a general tendency is noticeable to use mini or micro computer networks and to achieve the highest possible automation level. This is strictly connected with the advance of technology and the resulting price reduction of computers. This aspect is tackled by R.W. Goodwin[3]. Full automation of large, universal cyclotrons encounters considerable technical difficulties, however they can be overcome in "compact" type cyclotrons such as the C-30.

The control room of the C-30 cyclotron will be rather unconventional - strictly speaking there will be none. There will also be no "control console". As pointed out above the cyclotron should be operated without any special personnel. The role of the operator and the control room will be performed by a computer and its keyboard will be the control panel[6].

The control computer will be provided with software enabling the cyclotron start-up, maintaining required beam parameters as well as, in case of a breakdown, turning off the cyclotron according to a predetermined procedure depending on the nature of the breakdown. In case of a computer breakdown the cyclotron will continue operating for a certain time. All programs may be restarted and work resumed as soon as the breakdown cause is removed. Should the computer fail to assume emergency measures the control will be taken over by electronic circuits of the emergency switch-off and all cyclotron systems turned off in proper sequence in the emergency mode.

The basic INS computer equipped with appropriate terminals and software may be, if necessary, connected through a modems and a telephone line to a cyclotron control computer installed anywhere in Poland in order to perform a full diagnosis, an analysis of operational records as well as any operation as available from local control keyboard. In this way a it will be possible to conduct periodical check-up of the cyclotron thus preventing many emergency situations as well as to determine in detail the nature and cause of the breakdown. The information will ensure a reliable and efficient servicing of the cyclotron.

Control System Hardware

The computer of my choice is the IBM PC/AT 3 MB RAM with extended configuration, equipped with professional adapters (prototype), data acquisition and control adapters, analog-digital and digital-analog converters and appropriate software to be used in the multitask, single user mode.

This concept of control assuming highest possible computer use makes it possible to do away with most conventional control equipment. The remaining indispensable specialised electronic circuits are:

- amplifiers of signals controlling the cyclotron executing elements (received by means of optical fibres),
- multiplexer and demultiplexer for measuring and control signals,
- converters for measurement and control signals,
- cyclotron switch-off circuit which in case of a computer breakdown will safety bring all cyclotron systems to a standstill.

The control computer is connected to the cyclotron with not a single cable. The role of an information exchange channel is fulfilled by optical fibres which when used to connect in/out ports with analog and digital circuits have the following adwantages:

- absence of parasitic feedbacks on grounding,
- insensibility to electromagnetic distortions,
- absence of crossovers between channels,
- much faster transmission rate,
- no change of common to normal voltage,
- increased safety of work due to lack of short-circuits, grounding and feedbacks,
- low cost and ease of installation thanks to low weight,
- durability due to absence of corrosion.

The use of optical fibres in a cyclotron enables speedy installations in all conditions.

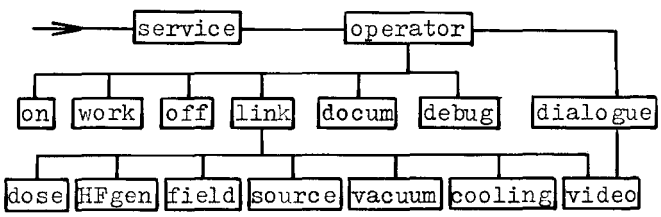
Optical fibres are connected directly to the computer bar by means of standard interfaces or converters while their opposite ends are connected to the sources of measuring and input of control signals. Output signals which control the work of executing blocks (power switches, motors, valves etc.) are amplified and shaped according to requirements.

Control System Software

From the point of view of software for control processes the cyclotron is divided into the following blocks:
- radiological protection
- RF generator
- magnetic field generator
- ion source
- vacuum
- cooling.

The control system is composed of a group of programs performing the following functions:
- servicing of cyclotron components
- communication, information exchange, records
- cyclotron control.

All programs are synchronous, with hierarchic structure, three-levelled with different priorities as depicted by the diagram below:



This programming structure facilitates modifications and developments according to new requirements.

All residing programs (loaded during the start-up of the control system) are permanently in the computer memory where, according to needs, they are either "put to sleep" or activated and can run synchronously and independently of other programs. Common for all programs are memory contents in the form of records, parameters and arrays of signals to which particular programs have access on a strictly determined principle of a critical section. All records and arrays are in the "linker" program. This makes it possible to restart the programs after a short breakdown without breaking the cyclotron operation.

Menagement Programs

"operator" - the program performs in sequence the following operations:
- checks state of flags of the equipment and controlled circuits, sends a sound and messages to the console showing the need to turn on power supply for a particular circ.
- starts the "dialogue" program and upon receipt of appropriate instructions starts the "turn on" program and other cyclotron servicing programs,
- enables control to be taken over by a terminal distant from the central computer,
- activates diagnosis procedures and the simulator in the case of emergency turn-off.

"service" - controls the modem and in case of a call generates interrupt signal for the "operator" and becomes a priority program linking the remote control terminal with the control computer.

"dialogue" - caters for the cyclotron control panel and enables:
- dialogue with the computer from the keyboard,
- printing on screen messages for the cyclotron operating personnel,
- alteration of standard diagrams shown on TVC,
- reading of any data controlled in the cycl.,
- alteration of certain parameters within predetermined limits.

Performance of the program is monitored and controlled by the "operator" program.

"turn on" - is initiated by the "operator" or "work". It contains a timetable for the particular equipment (pumps, field, RF, etc) to be turned on in proper sequence. It starts the cyclotron according to predetermined criteria first building up the magnetic field, then turning on the ion source and then turning on power of RF. After stabilization of parameters it hands over control to the "work" program and it may be restarted by this program. In case any of the parameters crosses beyond the regulation limits control may be handed over to the "turn off" program unless it is retaken by "work" before an elapse of a fixed period or any of the cyclotron circuits is beyond control.

"work" - takes over control after appearance of the beam nominal current. The scope of regulation of this program is narrow, sampling frequency is high and regulation settings small. Should any parameter go beyond the limits of regulation a "CAUTION" message will appear, the program will switch into the "turn on" procedure and the beam line will be cut off.

"turn off" - is started by the "operator" or "turn on". It causes sequential appearance at

fixed time intervals or upon occurence of a certain condition of a series of turning off signals, monitoring of execution, starting of final documentation procedure.

Communication and Documentation Programs

"debugger" - enabling software debugging by symulating the cyclotron operation without running it.

"documents" - controls the recording equipment for purposes of documentation.

"linker" - links the "operator" and other parallel programs of its level with servicing programs of particular cyclotron systems.

Cyclotron Systems Servicing Programs

All cyclotron systems servicing programs are initiated by the "operator" program as soon as conditions for cyclotron switch on appear. "dosimetry", "HF generator", "field", "source", "vacuum", "cooling", "video", programs controls and services the relevant installations of cyclotron.

During the cyclotron operation special circumstances may arise which cannot be handled by routine programs. In such situations the control system undertakes the following steps:

"CAUTION" - visual and accoustic signals, printing the signalling circuit on the main screen, after a determined period generating the "EMERGENCY" signal. It may be cancelled after the cause disappears or may be deblocked by the personnel.

"EMERGENCY" - an irreversible cyclotron state requiring switching off according to the switch-off procedure. It results in cutting off the ion line and activating the "turn off".

"BREAKDOWN" - a state requiring switching off the cyclotron according to the breakdown procedure desregarding the fact that programs servicing the various systems are operating.

Simulation

The simulator is a part of the control system included in software set and is used for testing the control programs. In a breakdown state it will be activated automatically after switching off the cyclotron in order to determine whether control programs, the operating system and the computer work properly. Results of the simulator performance will be the basis for remote cyclotron diagnosis.

Conclusion

The assumed control system and the use of optical fibreglass connectors remove the problems of struggling with disturbances, ensure separation of the computer from the power supply and the cyclotron itself, remove the possibility of many breakdowns and increase safety standards for cyclotrone users. A reliable computer and modern control technology will reduce the risk of a cyclotron breakdown and enable the beam to be employed directly for therapeutical purposes. Optical fibres are so far used in cyclotrons (e.g. IUCF, K800, Milan RIKEN) only for local information transmission however there are tendencies to increase their use. This is largely due to the advance in production technology of ready-made multipurpose fibreglass connectors.

According to a thorough estimate purchase and installation costs of a control panel, control equipment, power supply, equipment for elimination of disturbances and necessary wiring are much higher then those of a modern computer with optical fibreglass links.

References

1. Caen University: Ninth Conference on Cyclotrons and their Appl. Caen, France, 1981.
2. Mich.State Univ.: Tenth Conference on Cycl. and their Appl. East Lansing,Michigan, USA.
3. Goodwin R.W., Shea M.F.: Modern control techniques for accelerators. Tenth Conf. on Cycl.and their Appl. East Lansing,1984,s547
4. Bailey S.J.: Fiber optic data links near for industrial control. Control Engineering December 1978,s.32-34.
5. Goldberg N., Eibner J.A.: Optical link design and component selection. Computer Design, May 1979,s.218-222.
6. Yamazaki T.,Seki J.,Ogata H.: Central computer and on-line data processing. RCPN Annual Report, Osaka University, 1982.
7. Kumontis S.D.: PC features - what's optional, what's standard ? Instrument and Control Systems, 1980.
8. RCPN Annual Report. 1984,1985. The Research Center for Nuclear Physics. Osaka Univers.