PLC Application in the Control of CIAE-30 Cyclotron

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Abstract

Application of Programmable Logic Controller (PLC) brings CIAE-30 compact cyclotron into entirely automatic control, from cyclotron start-up until required beam current obtained at target can be performed with a single function key. The main parameters are sequentially set-up and regulated by PLC requiring no operators during routine production. High anti-interference ability, reliable safety interlocks, real time status monitoring and interchangeable operation modes of either full or half-full control, makes cyclotron reliable, stable, flexible and can display the dynamic status all the time. Processes of radioisotope production, e.g. targetry, chemical analyses, radioactivity monitoring and protection can be also performed with the same PLC.

The cyclotron has been commissioned over the last two years and proved that the hardware arrangement and software structure of the whole control system are practical and successful.

1   Relation between PLC and cyclotron

CIAE-30 compact cyclotron is a new kind of accelerator dedicated to medical radio-isotope production. Its main features are compact structure, low power consumption, high beam intensity and easy change of energy. It consists of complex equipment, e.g. external ion source, magnet, R.F. generator, stripper, vacuum, water cooling, pneumatic activator, transportation line, beam diagnostics, targetry and various power supplies. The whole production process includes H- beam production, acceleration, electron stripping, extraction, focusing, transportation, target control, radioisotope analyses and sampling. Fig.1 shows the main body of CIAE-30 cyclotron.

Automation of Cyclotron and production process need a compact and sophisticated control system to coordinate these devices, to deal with sequence control, parameter tuning, status display and human interface. The SIMATIC S5-135U Programmable Logic Controller (PLC) was chosen due to that it is more suitable for the task, especially, it can provide a simple and economic solution to the logic control, process automation and status monitoring. Furthermore, its standardized hardware and program section make it easy to assemble and program.

In order to couple with the standard input and output modules of PLC, special interfaces have be designed and added to cyclotron equipment [1]. They have some common specifications: sufficient electro-isolation ability; proper logical signal level; high accuracy analog message transmission; excellent anti-interference; reliable safety interlock.

The equipment interfaces, PLC and its peripherals build-up a complete control system and keep cyclotron always in a desired operation condition.

2   Hardware arrangement

The control hardware consists of two parts: PLC modules and operation console. See fig.2.

PLC modules include: three CPUs (922R), one coordinator (923C), a number of analog and logical I/Os, one communication processor (CP527), one intelligent processor(IP241), special bus and internal supplies [2].

Operation console includes: a keyboard, a large high resolution colour monitor, two encoders, beam diagnosis and a printer.

Fig.1 main body of CIAE-30 cyclotron.

PLC communicates with the cyclotron equipment through the logical and analog I/Os, which translate orders to and receive status messages from all the different devices. The PLC communicates with the console through the communication and intelligent interfaces, which receive operator instructions and transmit the processed status signals to be displayed on the screen or printed on

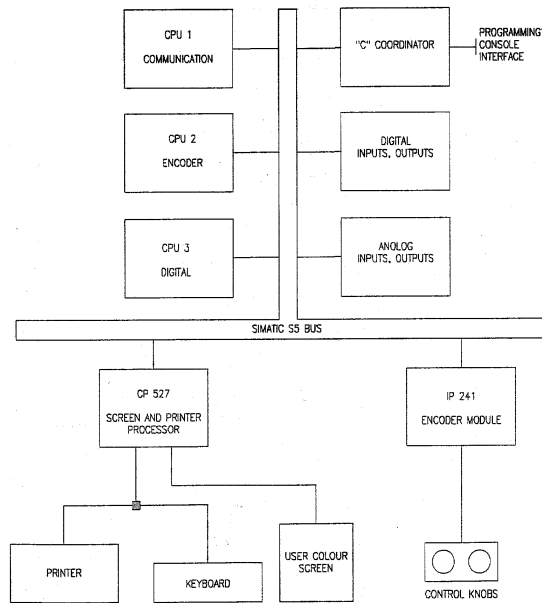paper. All analog parameters of the cyclotron can be adjusted using the two encoders.

Fig.2 hardware arrangement

Beam sensors are allocated along the beam path: axial injection line, acceleration chamber, extraction, transportation line and targets. Beam signals are pretreated by special interface circuits and then transmitted to the PLC for refreshing the storage and operation interlocks. In the meantime, the pretreated beam signals are also transmitted to the beam monitor on the console to be displayed simultaneously in three manners: digital, analog and ratio.

3 Software structure

The programming language of PLC used in CIAE-30 cyclotron is standard STEP-5 with four representations: ladder diagram (LAD), statement list (STL), control system flowchart (CSF) and, specially for sequential control, GRAPH-5. The four representations are equivalent and the user can choose the programming method best suited for control purposes [3].

Structured programming makes software user-friendly. The program can be broken into clearly defined technology-related sections - thus simplifying program development and modification. Standard function blocks provide self-contained complex function sequences that can be inserted as required at any point in the program. It makes programming simpler and quicker.

The complete program of the PLC consists of system program and user program. The system program contains all statements and declarations for internal function. It is an integral part of PLC and can not be changed by the user. The user program contains all statements and declarations programmed by the user for signal and sequence

processing.

CIAE-30 cyclotron user program is divided into many self-contained section blocks, called organization blocks (OB), program blocks (PB), function blocks (FB), sequence blocks (SB) and data blocks (DB).

OBs provide the interface between system program and the user program. PBs are used to structure the user program into the hardware model. FBs are programming units called frequently and repeatedly in complex functions. SBs are special types of program blocks for sequence cascade. DBs are used to store data and texts.

These blocks can be 'nested' in the user program. The maximum permissible nesting depth is 24 blocks.

The complete user program is divided into three parts and saved separately in three CPUs according to different functions: logical, analog and communication. The three CPUs operate in parallel and are synchronized by the coordinator.

4 Operation features

The cyclotron status can be clearly graphically displayed on the monitor screen. These screens are called 'page's. Every page not only displays the key parts of the different systems, but also gives the real time dynamic messages by changing colour or positions. Different pages also assign different meanings to the function keys, according which the operator can choose appropriate instructions to the PLC. Fig.3 shows the page structure of the operation synopsis.

Two encoders can be assigned to any of the analog parameters for tuning at any time. These parameters directly determine the cyclotron specifications, e.g. beam energy, intensity, extraction efficiency and ratio of the beam distribution among different targets.
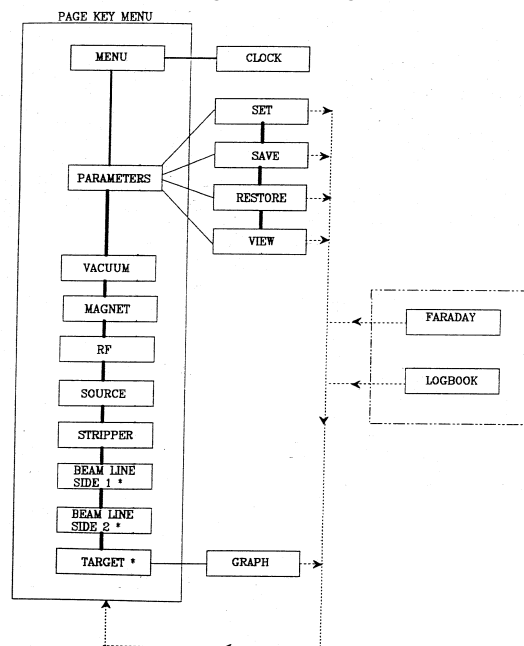

Fig.3 page structure

Different set of parameters can be stored into the PLC library, which is able to contain up to 50 sets and any of them can called into operation when necessary, that significantly saves machine tuning time and improves operation efficiency.

The PLC can operate in two modes: full automation or half automation. In the mode of full automation, the cyclotron can automatically start-up by pushing one function key, including turn on power supplies, cooling water, vacuum, set up the magnet, R.F., ion source step by step and, put the strippers into correct positions, until the desired beam is obtained on the target. In the mode of half automation, the PLC divides the whole sequence into different sections. At end of every section, operator interventions are required but, the operation sequence and safety interlock are also managed by the PLC. The full automation mode is suitable for routine production and the half automation mode is suitable for machine maintenance and equipment test. The two modes can be transferred at any time.

The CIAE-30 cyclotron and its PLC control system have been commissioned since 1995. More than two years of operation practice has proved that PLC application in the control of cyclotron is user-friendly, flexible, reliable and, the hardware arrangement and software organization of the whole control system are suitable and successful.

References

[1] PLC Control system and Equipment interfaces of CIAE-30 Cyclotron, Internal, CIAE.
[2] Manual, S5-135U Programmable Controller, SIEMENS.
[3] STEP-5, Programming Package for Personal Computer, SIEMENS.