RENEWAL AND AUTOMATION OF THE ATOMKI MGC-20 CYCLOTRON

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Abstract

This paper reports on the large-scale renewal project of a compact multi-particle cyclotron, aiming at the improvement of the reliability and flexibility of the operation. Major subsystems including the vacuum, the gas-supply and the control systems have been partly or completely redesigned and rebuilt. The applied solutions and the achieved results are presented, showing a middle-aged cyclotron being half-way on the road to a nearly one-button machine.

1 INTRODUCTION

The MGC-20 cyclotron of the Institute of Nuclear Research of the Hungarian Academy of Sciences - manufactured by the NIIEFA, St. Petersburg, Russia [1] - has been in operation for 15 years. Protons, deuterons, $^{3}He^{2+}$ and alpha particles can be accelerated with extracted beam currents up to 50 μA. The cyclotron has been used for a broad range of scientific and applied programmes, extending from nuclear spectroscopy studies to routine production of short-lived radioisotopes for medical examinations. The yearly time of operation is around 4000 hours with over 60% beam-on time share.

The accelerator and all of its subsystems were designed and constructed during the early seventies. Numerous systems and components have not only become obsolete since then but are approaching the end of their lifetime as well. To provide reliable operation for a long time a large-scale renewal project has been implemented. The reconstruction was supported and partly financed by the Technical Co-operation Programme of the International Atomic Energy Agency [2].

2 SCOPE OF THE PROJECT

2.1 Renewed subsystems

Surveying the status of the different subsystems and considering the available resources, two key areas were selected to be the main objects of the reconstruction. The vacuum and the control systems of the accelerator facility were not only in the worst condition but their modernisation promised the most benefit from the point of view of reliability and flexibility.

2.2 Vacuum system

The renewal of the vacuum system included almost every component of the original hardware. The layout and the control of the system were also modified in accordance with the new units. Main parts of the reconstruction were as follows:

- *Cyclotron vacuum chamber*

The working vacuum in the cyclotron chamber and the RF-resonator was provided by three diffusion pumps of 700 l/s nominal pumping speed. The fore vacuum system consisted of two rotary pump stations - one used as the common backing stage for the diffusion pumps and the other for rough pumping. With the exception of the gate valves of the diffusion pumps, which were driven by motors, all valves in the system were operated manually.

The available resources did not allow the replacement of the old diffusion pumps, but the rest of the system was completely renewed. Two high performance Edwards E2M80 rotary pumps have been installed in the fore vacuum system and all manual valves have been replaced by pneumatic ones.

- *Beam transport system*

The vacuum system of the beam lines consisted of three Roots-type pumps installed near the target locations in different rooms and twelve ion-getter pumps distributed all over the system. The latter ones were used up very much and significant maintenance was required to keep them running. The gate valves separating the different sections of the beam lines were driven by motors and they operated rather slowly.

All the ion-getter pumps were dismantled and eight new Edwards 100/300P diffstak units (300 l/s) have been installed. Each unit is equipped with a rotation pump which can be used either as a backing or a roughing stage. The fore vacuum and butterfly valves of the units are all pneumatic.

The gate valves in the transport system have been replaced by pneumatically driven ones, allowing computer control and fast opening/closing process.

- *Vacuum measurement*

The outdated measuring units and heads have been replaced by Balzers TPG-300 units and new Pirani and cold-cathode gauges. An interface circuit has been developed which sends the measured fore and high vacuum values from each channel of the units to the process control code running on a personal computer.

2.3 Gas-supply system

The components of the original gas-supply system were located in three separated rooms and did not allow any remote control. All the valves in the system could only be operated manually and it required lots of walk from the operators and took about 20 minutes to change the working gas in the ion source.

The system has been completely redesigned. High pressure solenoid valves were installed instead of the manual ones. The obsolete needle valve was replaced by a Tylan FC-280A mass flow controller, providing precise control of the gas amount in the arc chamber of the ion source. Connections to the rough pumping system of the cyclotron have been provided through pneumatic valves.

2.4 Control system

Perhaps the most obsolete part of the cyclotron facility was the hard-wired relay-based control system. Any modification in the layout or in the control process was very difficult to do and it did not allow any computer support for the operation.

Programmable logic controllers (PLC) are more or less standard devices for the control of small and middle-sized cyclotrons. These industry standard systems combine flexibility with high reliability and require relatively limited man-power and development time to build a complete solution. Based upon our good experiences with Mitsubishi PLCs used at the isotope production target station, the Mitsubishi Melsec A family was selected for the control of the cyclotron facility.

Figure 1 shows the architecture of the new control system. There are three PLC units on the process control level which are dedicated to different parts of the facility. The main unit, the master PLC, controls the cyclotron and the beam lines, the local unit Nr.1 is responsible for the vacuum and gas-supply and the other one is for the radiation safety interlock, cooling and ventilation systems. Since the power supply room is in the basement, numerous modules of the master unit were placed in a remote station located there to decrease the number of the required cable connections. All units are connected together through the 1.25 Mbps fast double-loop MelsecNet network. The system has 706 digital and 210 analogue I/O points at present.

Three personal computers running Windows NT are applied on the operator interface level. They are connected to each other and to the master PLC through a thin ethernet private network. The NT server machine plays the role of a gateway between this segment and the local area network of the institute.

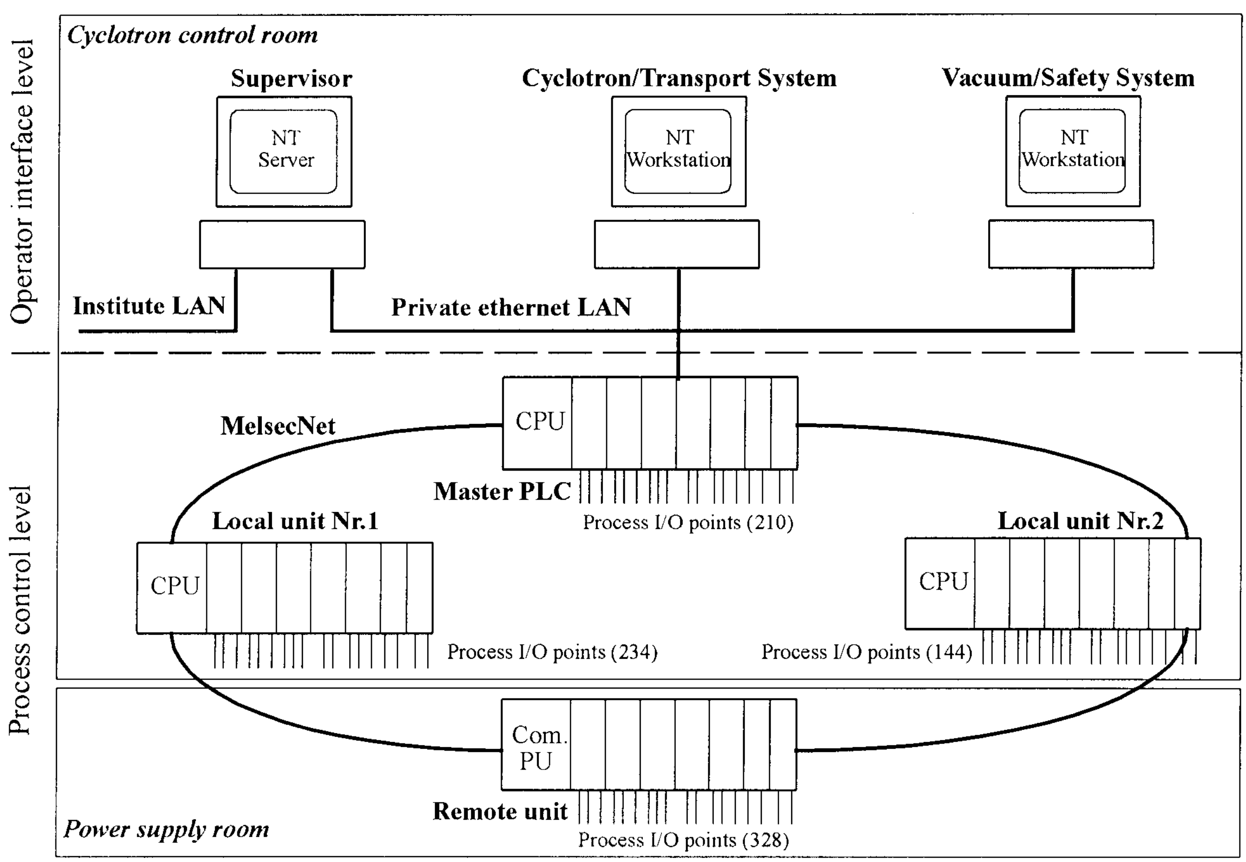

Figure 1: The architecture of the new control system applying networked PLCs with a total number of 916 I/O points.

3 CONTROL AND AUTOMATION

The control codes for the PLC-stations were written in the Melsec Medoc assembly language. They provide stand-alone operation for each unit even with switched off operator interface. The implemented architecture keeps data exchange between different units as low as possible. The highest rate is required between the master and the remote stations, the maximum of the communication delay is below 40 ms. The cycle-time of the assembly programme is about 30 ms in the local units and approaches 100 ms in the master one.

The high-level control programme was developed using the Paragon TNT industrial process control software package. The networked client-server architecture of this software provides a very flexibly configurable environment. Each control task can be designated to any computer and new tasks can be added or extended very easily. Highly informative graphical user interfaces can be developed, which display the status of the controlled devices together with their control elements. The rate of the data refresh can be selected in accordance with the priority of the process. The used 0.5 and 1 s refresh periods assure nearly real-time operation.

All the new elements have been connected to the PLC-system. As a result, the control of the vacuum and gas-supply systems has been improved significantly. The sequential starting and stopping processes of the diffusion pumps have been completely automated - they can be initiated with a single mouse-click. The time required for gas change in the ion source has been decreased remarkably - the process is fully automated and it takes less than 2 minutes now.

In addition to the renewed systems the control of the old ones is modified as well. The most important part of this work was the implementation of computer control for the cyclotron and beam line power supplies. The cyclotron has a rather complicated beam transport system with long beam channels and numerous ion-optical elements. The total number of coil and magnet power supplies are 36. As a consequence, to change the setting usually required at least 20-30 minutes with the traditional control desk consisting of selector switches and up/down tumblers for the motor-driven adjusting potentiometers.

The transition to computer control requires interface units which are isolated from the PLC-ground and allow the connection of the control electronics to the D/A and A/D modules. A two-channel (control and measurement) interface circuit has been developed, applying the TIL300 opto-isolators, which provides the necessary separation and linearity for each power supply.

The digital control of the units requires adjustment elements of new type, which can be connected to any D/A channel and allow easy and convenient value setting. One of the best suited device for this task is the optical shaft encoder. A new adjustment unit with two shaft encoders has been developed. Its interface circuit generates pulses for the PLC's interrupt module during the rotation of the shafts. These pulses interrupt the main control code and start the service routine, which modify the control value of the selected D/A channel accordingly.

The digital control values of the power supplies can be saved and loaded easily. A Microsoft Access database was created to store all those values which are necessary to repeat a successful setting. The tuning time of the different beam regimes has been decreased by about a factor of 10 in this way. The reproducibility is excellent, just a few very small adjustments are needed to optimise the setting after loading the saved values from the database.

4 CONCLUSION

The renewal project was very successful. Not only reliability has been increased, but the operation of the accelerator has become simpler and easier as well. The time to change a beam regime has been decreased significantly - the experiments with short irradiation time are now much more economical than before.

The selected methods and solutions proved to be very efficient. All the design and construction could be performed with the limited resources of the cyclotron department. The renewal was carried out parallel to the routine operation, the cyclotron was available for the users without any limitation during the project.

REFERENCES

[1] A. V. Galchuk et al., Proc. of 9th All-Union Conf. on Accelerators, Dubna, USSR, 40(1985)
[2] IAEA Technical Assistance Programme - Project Code Number: HUN/4/013