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EXPERIENCE ON THE APPLICATION OF AUTOMATED CONTROL SYSTEMS FOR CYCLOTRONS WITH DIFFERENT ENERGIES OF ACCELERATED PARTICLES

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Abstract

In the report are given the results on the development and application of automated control systems for a series of cyclotrons designed in the JSC “NIIEFA” with energies of accelerated hydrogen ions (H^-, D^-) from 1 up to 80 MeV.

INTRODUCTION

The JSC “NIIEFA” was a pioneer in the development of cyclotrons in our country. For more than seventy-year history, more than thirty five types of cyclotrons [1] have been designed. Development computer technologies set a task of creation of a system of automated control for cyclotrons.

THE FIRST EXPERIENCE ON THE DESIGNING OF AN AUTOMATED CONTROL SYSTEM FOR CYCLOTRONS OF THE CC SERIES

In 2006, the development of a new series of cyclotrons with acceleration of negative hydrogen ions (H-, D-) was started. The first two cyclotrons CC-18/9 of the new series were intended for the Hospital of the University of Turku, Finland and Russian Research Center for Radiology and Surgical Technologies, Pesochny, St. Petersburg, Russia.

The main element of the ACS for these cyclotrons was the powerful MELSEC System Q PLC from Mitsubishi Electric with expansion modules for connecting all types of signals used in the cyclotron ACS.To reduce the length of connecting cables, 2 passive stations on the basis of MelsecFX2N 32DP module intended for data remote acquisition were placed in the cyclotron hall. These stations are connected to the central PLC as slave Profibus-DP modules (see Fig. 1).

As the operator's console, a personal computer on which the Windows application is installed is used. The software of the central programmable logic controller totally controls all the systems of a cyclotron.

In 2006-2007, both cyclotrons were successfully delivered to customers and continue to work until now. However, in the process of adjusting the cyclotron equipment, the main drawback of the ACS with a single controller was revealed - if there is a need to make changes in the software, it is necessary to stop all cyclotron systems, which significantly slows down the adjustment procedure. Another drawback of this ACS was the use for measuring beam currents of standard ADCs intended for measuring slowly varying signals. The current measurement was not highly accurate. In addition, in the process of intensive operation of the cyclotron, part of the electronic equipment in the cyclotron hall has broken down over time, because of the high radiation level.

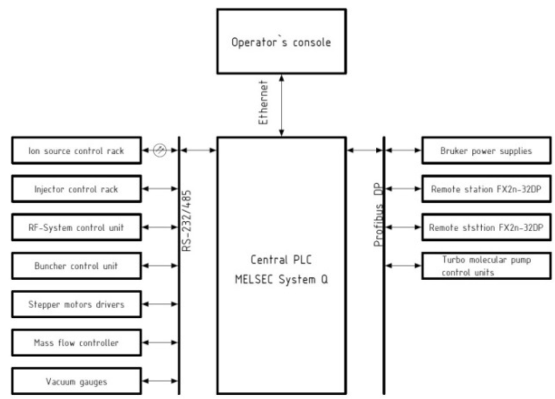

Figure 1: Block-diagram of the 1st ACS for cyclotrons of the CC series.

ACS OF THE 2-ND GENERATION

In 2007, the development of two cyclotrons was started: MCC-30/15 for delivery to the University of Juvaskula, Finland and CC-18/9 for FSUE "RFNC-VNIITF", Snezhinsk, Russia.

The following tasks were set during the development of ACS of these cyclotrons:

- Remove the drawback of ACS with one control controller and reduce the time of adjustment of equipment.
- Place electronic equipment in a radiation-safe place.
- Create a unified ACS suitable for cyclotrons of different types.
- Develop a high-quality system to measure the beam currents with a high-speed ADC and a possibility for the beam oscillogram display.
- Develop advanced RF-system control unit based on an industrial computer with digital synthesis and processing of signals built in an FPGA-based module.
- Provide the ability to connect several operator work-stations.

To solve these tasks, it was decided to create a control system with a distributed architecture (see Fig. 2).

The main element of the control system is the central computer, which is the server of the cyclotron modes database. It controls the data transfer between sub-systems and automatically starts sub-systems. Only

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vacuum sub-systems procedures are realized by controllers.

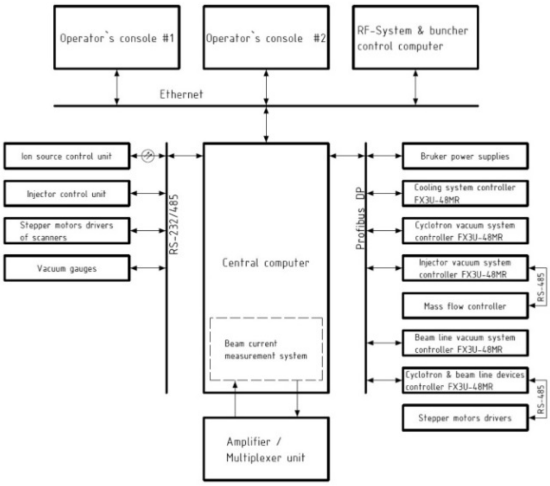

Figure 2: Block-diagram of an ACS of the 2nd generation.

As a result of the adjustment of the ACS, the following problems were revealed:

- When rebooting the central computer, the Profibus master buffer was cleared, which resulted in the switch- off of the rest units of the network. The problem was solved by using additional service signals to synchronize the data transfer between the units of the network.
- Under ACS long-term operation, acquisition of data of the current measuring system failed. We could not find the exact cause of the problem; it may depend on specific features of the ADC driver. However, by the software modification we managed to minimize its occurrence to once in a few days. Rebooting of the computer allowed the problem to be eliminated.

In 2010, the MCC-30/15 and CC18/9 cyclotrons were successfully delivered to the customer and put into operation. The operation of these cyclotrons is currently ongoing.

ACS OF THE 3-RD GENERATION

Starting from 2010 a new automatic control system wasdesigned for the four cyclotrons of different types – CC-12 cyclotron operated in the JSC«NIIEFA», the CC-18/9M delivered to the JSC «NIITFA», Moscow, Russia, the CC1-3 delivered to the Vinca Institute of Nuclear Science, Belgrade, Serbia and the C-80 delivered to the PNPI, Gatchina, Leningrad region.

These cyclotrons have significant differences in the complete set of used equipment, primarily in the beam transport line. In order to unify the ACS, Advantech ADAM-4501 controllers and some of Mitsubishi FX3U controllers are replaced with Fastwell-I/O controllers because they allow, by changing the number of expansion modules, to create a system that meets the needs of the cyclotron as much as possible. Improvements were made to eliminate defects identified in the previous version of the ACS. The ADC of the beam current measuring system was moved in a separate computer. This allowed us to solve the problem of data acquisition freezing from current sensors. Another Mitsubishi FX3U controller was added, which took over the tasks of the Profibus DP network master and the management of the security and interlocks system (see Fig. 3).

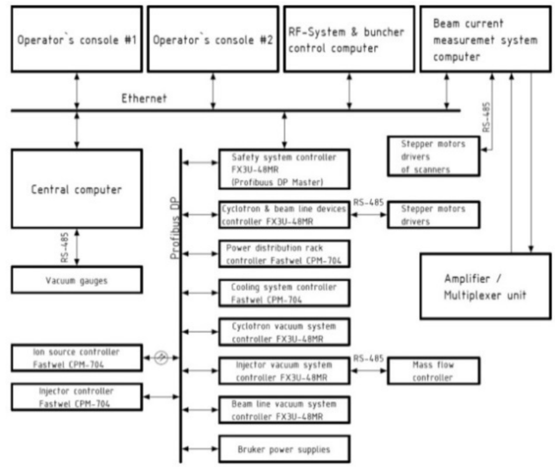

Figure 3: Block-diagram of an ACS of the 3rd generation.

The workplace of the operator's console is equipped with two monitors. At the first, the interface of the cyclotron subsystem control program is displayed, and the interface of the beam current measurement program is displayed on the second one (see Fig. 4).

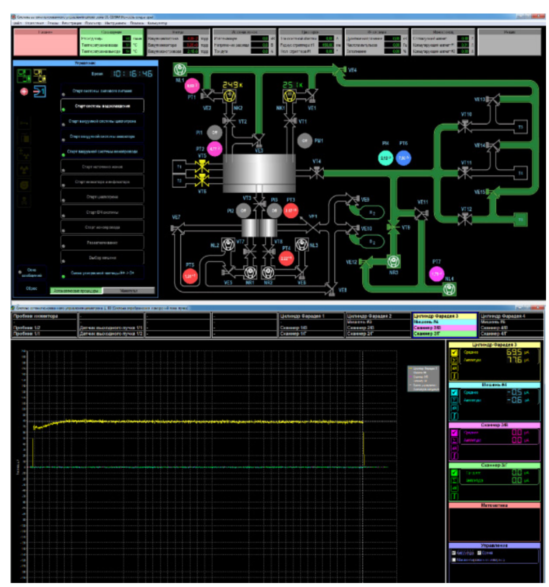

Figure 4: The windows of the main program and the beam measurement program.

This ACS proved its effectiveness and nowadays it is successfully operated in all 4 cyclotrons. However, in the process of operation one drawback was revealed. The bandwidth of the Mitsubishi FX3U controller system bus (the Profibus network master) was insufficient to transfer a necessary volume of data. The solution was found in dividing the data array into small amounts, but this

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reduced the program performance, and as a result appeared a delay up to 1 sec in the information display and program response to a command.

ACS OF THE TARGET SYSTEM

Since 2014, the JSC "NIIEFA" delivers target systems of own production. ACSs of these systems are fully independent and are built on the basis of Mitsubishi FX3U. The Mitsubishi GT1275 graphic operator console is used as an operator workstation (see Fig. 5). The controller and operator workstation are networked via the Ethernet Protocol.

The first target complex was delivered to the JSC «NIITFA», Moscow as part of a complex based on the CC18/9M cyclotron, where it showed a high efficiency of radionuclide production. The ACS of the target complex successfully and reliably fulfills its functions[2].

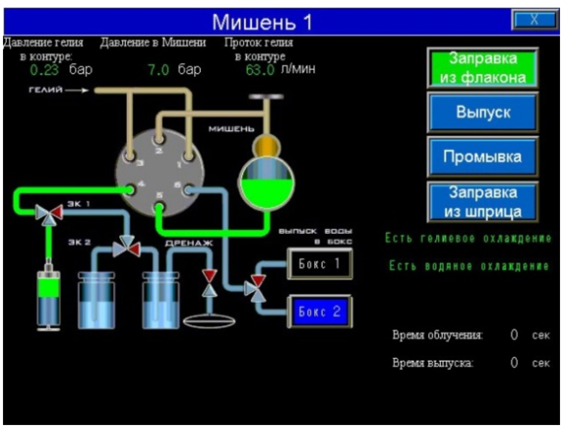

Figure 5: Control window for the water target.

ACS UPDATED ACS FOR CYCLOTRONS

In 2017 JSC Rusatom Healthcare signed a contract for the supply of a cyclotron complex to the Thailand Institute of Nuclear Technology, Bangkok. The complex is built on the basis of the cyclotron CC-30/15. JSC "NIIEFA" is the co-executor of this contract and is responsible for the development and manufacture of the CC-30/15 cyclotron, the beam transportation system, the target complex for irradiating solid targets and the sample irradiation system. At present, the development of this cyclotron complex and automatic control system for it is under way. In this project, the team of developers, using the accumulated experience of development and operation of previous ACS, produces the necessary improvements of the system, caused by the expanded functionality of the complex, new solutions and bundling of cyclotron systems, and also eliminates the identified shortcomings of previous ACS.

The main modifications of the ACS of the new generation of cyclotrons are as follows:

- As a central controller of the automatic control system, a powerful controller of Mitsubishi Q-Seies.
- The new Mitsubishi controllers FX5U and Fastwel-IO series (CPM713 and CPM723) are used as slave controllers.
- Profibus DP fieldbus has been replaced by the Industrial Ethernet Protocol Modbus/TCP.
- Reduced the number of controllers by combining the functions of several controllers in one (for example, in one controller the control of the vacuum systems of the cyclotron and the system of external injection).
- Control of the vacuum system and diagnostic devices of the beam transport line is allocated to a separate system (separate rack) (see Fig. 6).
- Extended functionality of the ACS (management of operators' access to work, automatic documenting of events (operational journal), displaying a graph of the cyclotron complex main parameters).
- The control subsystem of the target complex is integrated in the ACS.
- It is planned to realize remote control elements for the cyclotron complex via the Internet (at present stage - remote monitoring of the complex system parameters and remote management of the operators' databases).

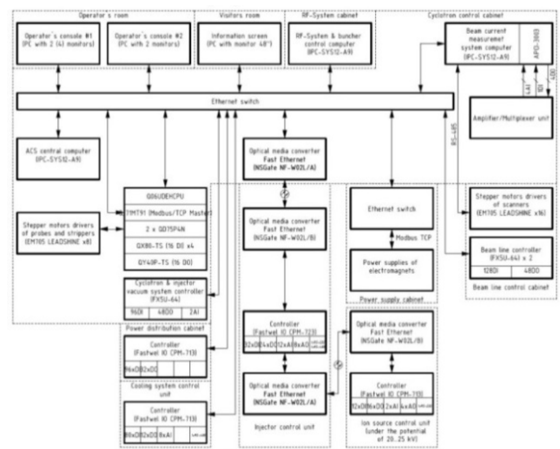

Figure 6: Block-diagram of an ACS of the cyclotron CC-30/15.

CONCLUSION

The staff of Scientific and Technical Center "LUTS" of JSC "NIIEFA" has extensive experience in building ACS of cyclotron complexes. These ACS successfully function at many objects not only in our country, but also abroad. However, the ACS is constantly evolving, faults are eliminated, new solutions are applied that can satisfy the customer's requirements.

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