

## DEVELOPMENT AND IMPLEMENTATION OF THE AUTOMATION SYSTEM OF THE ION SOURCE FOR BNCT\*

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### Abstract

To operate a source of negative hydrogen ions an automatic distributing control system was developed. This system consists of master controller (Slab C8051F120) and a set of peripheral local controllers (PLC) based on microcontroller Slab C8051F350. Using an optical link between PLC and master controller there was created a system resistant to high-voltage breakdown of the ion source.

To control the system, a special programming language has been created. It includes procedures for checking the necessary parameters, setting the value of the physical quantities to simplify the experiment, verifying the lock status and protection. This system provides two programmable timers, as well as procedures in emergency situations, such as: lack of water, poor vacuum. It can be operated in semi-automatic mode, if the script asks operator about preferable actions and then continues the script depending on the response. All scripts are performed in master controller, and this makes system very rapid (for example system response time is 1 ms).

### INTRODUCTION

One of the most important stages in the development of new facilities is to automate and connect all control units together. To achieve this goal, the automation of power supply units in the new ion source injector was carried out. The ion source injector is located in a research facility BNCT [1]. This method of treatment is very effective against a number of currently incurable radioresistant tumors, such as glioblastoma multiforme and metastatic melanoma [2, 3]. Frequent changes of control commands and their parameters during experiments cause serious problems. Therefore, the scripting language consisting of control commands was developed. It allows operator to implement all sorts of automatic control algorithms and conduct experiments with minimal outer control. Automation, conducted within the framework of this work, simplifies significantly the operation of the facility.

### SUBJECT AREA

The ion injector comprises several high-voltage power sources, temperature and vacuum level nodes, requiring remote control and data capture.

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Power sources are controlled by identical and interchangeable modules of programmable logic controller (PLC), receiving commands from a personal computer through a switch. Each PLC has a microcontroller and several analog and digital channels, which are connected via serial interfaces SPI & I2C with the PLC microcontroller. The microcontroller allows operator to test devices on the board if they are connected with each other. In conditions of high electromagnetic noise the distributed control system with sufficient independence of modules increases the reliability of the entire control system.

The structure of the control system is shown in Fig. 1.

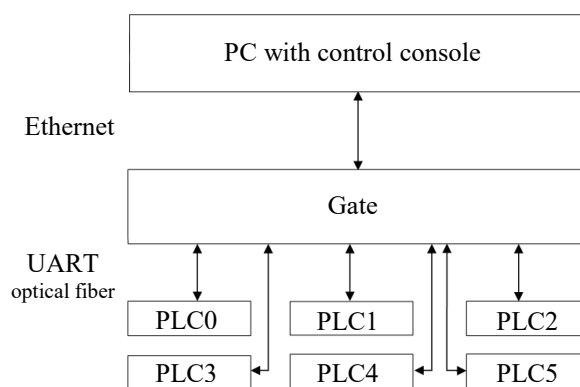


Figure 1: Structure of the control system.

### ALGORITHMS

Commands are usually repeated during the experiment and for convenience to operator algorithm scenarios have been developed. Operator can create a certain set of commands once and then these commands can be repeatedly applied. Command can be as unconditional execution of some action, and also it can be a check of channel status. After checking it is possible to jump to another line in the scenario.

The switch algorithms allows user to apply two modes: manual and automatic. In manual mode, the operator can change the values of PLC. On the other hand, automatic mode allows user to run the script, which will perform the control over the experiment without operator. A block diagram of the basic algorithm is presented in Fig. 2.

The developed switch algorithms allow user to control automatically the ion source. Link between the management console and the switch is not required. Accordingly, if the operator console suddenly loses contact with the switch, the experiment will not stop, and the switch will continue to capture the critical parameters

of the experiment. If these values are exceeded, the switch takes some measures that were initially set by the user.

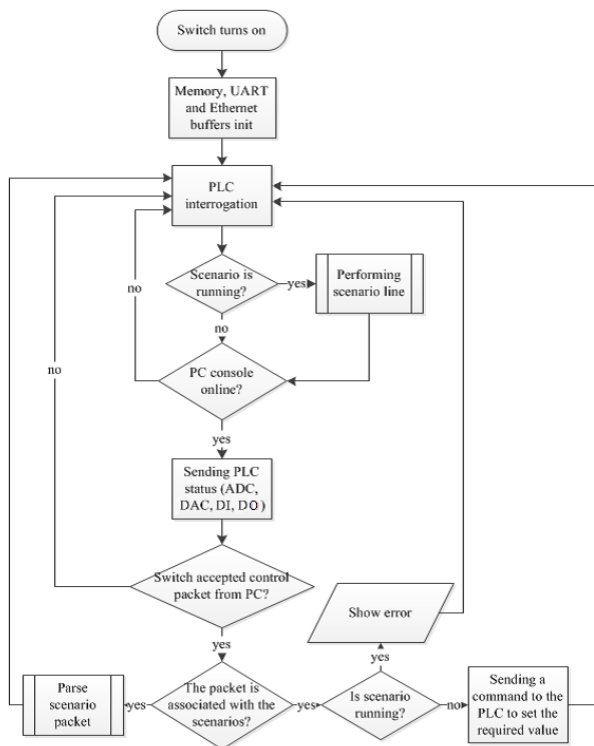


Figure 2: The basic algorithm of the switch.

## SCENARIO

Scenarios – a set of strings that contain parameters such as the block number, channel number, the command, the value of the team and its priority.

The sequence of operations required depends on checking of states and transitions. Therefore, an internal control programming language was created – scripting language. To measure the time intervals the internal timer of microcontroller was used, which hosted four logical timers with a period of one millisecond. All script parameters are translated into physical quantities, so the operator can control experiment simply. Scenarios allow us to describe the action in emergency situations, such as a lack of cooling water, poor vacuum, etc. If this happens, the console informs the operator about the error. Scenario processes by the switch and that allows user to instantly respond to emergencies and not waste time waiting for a response from the PC.

Block number denotes the index card PLC, which will use certain equipment. The channel number indicates what kind of equipment can be used. User can choose ADC, DAC, digital inputs (DI, 1 bit ADC) or digital outputs (DO, 1 bit DAC). The command can be either set the value or values of the comparison device with the parameters specified by the user. Execution priority specifies how the command will be executed: normally, rapid or emergency. After the command with normal priority it is exhibited a delay in one second. Rapid command is executed without delay. Command checking

emergency are executed before each execution line in the script: on stage startup script host controller stores the row numbers and emergency script before executing the next line in the script ensures rapid implementation of all emergency lines.

User has an opportunity to write the values in the array of intermediate calculations, for example for the implementation of various filters.

Automatic control is realized by algorithms which are stored as data files in the controller memory. Microcontroller has built-in memory, but depending on the complexity of the scenarios it may not be enough. To solve this problem, the anchor controller is equipped with an external memory to 32 KB.

For transmission lines in the script, you must first compile them using the built-in compiler, and only then operator can transmit control commands to the switch. All lines of the script have the same number of parameters. Each parameter – a signed 32-bit number.

## HARDWARE

The programming code implements the developed algorithms and allows switch to receive pre-programmed in the console operator scenarios, to change values on the PLC through the console and send the values of recorded parameters to the operator. Program code was written in C language with the help of SiLabs utility.

## THE SWITCH

The switch is a "bridge" between the Ethernet channel and the UART interface. It also processes its own programming language, which allows operator to organize the automatic control equipment. Switch hardware:

- microcontroller C8051F120;
- RAM memory K6X4008T1F 32 KB;
- Internet module CP2201;
- two-channel UART buffer SC16IS752.

## THE PCL

The PLC board is used as a direct control unit, which interacts with high-voltage power sources. Every PLC contains 8 ADC (16 bit, 0-5 V), 4 DAC (16 bit, 0-10 V), 8 DI and 8 DO. Every PLC communicates with a switch through opto fiber lines. After the switch is turned on, it queries all PLC one by one. All data transfers between these devices according to a certain algorithm, which allows switch to send the unlimited length of the packet data. PLC hardware:

- microcontroller C8051F350;
- 8 16-bit ADC with a range from 0 to 5 V;
- 4 16-bit DAC with a range from 0 to 10 V;
- 16 optocouplers SFH628A;
- Instrumentation amplifiers INA129;
- 16 I / O ports I2C PCA9539.

## PC CONSOLE

Control of source of negative ions is performed using the program created in LabView environment.

The program allows user to work on manual and automatic control. The user is provided with a special language that provides the implementation of various management scenarios, as well as the handling of emergencies.

The attendant console is implemented so-called "scenario editor", allowing user to create scenarios. The editor allows you to save the script in computer memory and load them into the program. It also allows you to select a control channel by its name. All names must be assigned to a special configurator, which is composed of the management console. Before sending the script to the switch user have to compile it by program means. During compilation program check all the lines in the script, conversion of physical quantities in the codes for DAC / ADC and the conversion of all the rows in a clear view of the switch.

## IMPLANTATION

The developed system has been successfully tested on stand without high voltage. Designed scenario worked for 3 hours. Testing algorithm consisted in that the inputs are shorted to the outputs. When value on output is set, program checks the value of the input.

However, after mounting the system showed some problems. Raising the voltage to 22 kV, switch starts to hang out.

The first step was connecting high frequency noise filter to avoid noise on power rail. It did not help, and on the next step the switch connected to the DC-AC converter from an external battery. It helped, but not much.

After the diagnosis of board components, has been found a fault in the quartz generator: its timing diagrams were very noisy and the component was soldered with nearby components. It also didn't get good result.

Because of features of media converter switch board has been connected to it via an Ethernet-switch, which was powered from the rack without filters. It was suspected that power noise passed through a switch to a switch via Ethernet cable. However, after connecting to an external periphery of the battery much change has not occurred.

The next step was to design grounded box for peripherals and switch board. But placing the apparatus into it allow operator to work twice longer. After that, in the switch watchdog timer have been activated, but it also does not give much result.

For further possibilities of the experiment it was proposed and implemented following solution: in the absence of a signal from the switch control program sends a reboot signal to the remote relay module ADAM 6066, connected to the switch. This solution is not ideal, because operator loses control of the experiment within 1-2 seconds, but it takes place, while our laboratory is looking for other solutions.

Now we are working on integration of hydrogen diagnostics and control.

## RESULTS AND DISCUSSION

The developed and tested control system allows operator to perform experiments with minimal operator control. It improves the operational characteristics of the facility, including the protection of the patient from operator errors. At the same time this system allows operator to interact with the elements of the installation without much effort.

This system is easy to operate, so it is possible to integrate it into other hardware and control systems. Simplicity of replacing of burned-out modules allows to repair the ion source in a few minutes. Also, when you connect the adapter for PLC, which was developed earlier [4], it is possible to apply this management system in any other assigned. To control high voltage sources created and integrated system need to be upgraded. We are looking for opportunities to fix high voltage noise problem. With the help of temporary solution experiment can be carried out.

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