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PHYSICS AND TECHNIQUE OF ACCELERATORS

Design of the New Control System for Linac-200

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Abstract—The construction of an experimental facility with test electron beams is under way at the Dzhelepov Laboratory of Nuclear Problems at the Joint Institute for Nuclear Research (Dubna, Russia). The facility is based on the MEA accelerator that was transferred from NIKHEF to JINR at the beginning of the 2000s. Despite the long service life of the accelerator, it is in good condition and still has a significant operation potential. The linac is being commissioned and the first 200-MeV beam has been generated. For now, the machine is controlled by a set of standalone subsystems that were created as required. Certain systems (e.g., vacuum) are controlled and monitored locally. However, a global control system is required to operate the accelerator as a user facility. The system requirements are formulated in this paper. The key issues of controlling the accelerator and its auxiliary (evacuation, cooling, etc.) systems are considered. The design of a new Tango-based control system of the Linac-200 is presented.

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INTRODUCTION

The Linac-200 is a linear electron accelerator with the energy up to 200 MeV. The accelerator is intended to carry out scientific and methodical research in accelerator physics and technologies, aimed at the design and elaboration of elementary particle detectors at the Dzhelepov Laboratory of Nuclear Problems, Joint Institute for Nuclear Research (JINR), and to carry out applied research. The accelerator consists of an injector, a buncher, and four accelerating stations (A01–A04) [1]. In the future, an installation of nine more accelerating stations (A05–A13) is planned to increase the electron energy to 800 MeV. After each station, the beam extraction for users will be arranged.

1. GENERAL STRUCTURE

The basic controlled objects of the accelerator are as follows:

(i) vacuum system;

(ii) focusing and steering magnets;

(iii) electron gun;

(iv) thermostabilization system;

(v) synchronization system;

(vi) RF system: master oscillator, preamplifier, diagnostics of forward and reflected waves;

(vii) accelerating system: status, pulse formers.

In addition, the control system should have access to information from diagnostic devices and the radiation monitoring system and include an interlock and signalization system.

2. TANGO CONTROLS

The Tango Controls toolkit [2] was chosen to implement the centralized control system. Its advantages are as follows:

(1) Free-of-charge. It is open-source software.

(2) Well-developed. Tango has more than 20 years of history; the system was developed by a collaboration including more than 50 organizations and more than 500 individuals [3].

(3) A considerable number of auxiliary programs for generating code, administering, etc.

(4) Cross-platform basis and support of several programming languages for both server and client applications.

(5) Well-developed API.

(6) Scalability.

(7) A significant number of ready-made classes of devices in the repository (although most of those can be used only as an example for elaborating individual devices, e.g., due to the fact that they are based on libraries used by particular developer institutions).

Table 1. Datasheet on magnets of the accelerator

Magnets	Number of channels		Voltage, V	Current, A
	Linac-200	Linac-800		
Focusing				
Klystron coils	13	40	250	10
Injector lenses	2	2	30	1
Buncher solenoids	3	3	100	5
Section solenoids	9	9	500	5
Quadrupoles	4	22	40	3
Steering				
Steerer upstream the buncher	2	2	150	3
Steerer downstream the buncher	2	2	50	3
Other steerers	16	34	10	3

(8) Availability of experience at the JINR, since the Tango software was chosen as the basic tool for creating the control system for NICA collider.

3. CONTROLLED OBJECTS

3.1. Vacuum Equipment

3.1.1. Power supplies of ion pumps. The following power supplies are used at the accelerator:

(1) Power supplies used at the MEA (the option of remote control is absent; however, there is an option of monitoring the operating current and consequently the vacuum value):

(i) Varian 929-0172 units presently supply the majority of pumps through the DIGEL splitters. The information on the operating current is taken from the splitter in the form of an analog signal with an amplitude of 0–5 V.

(ii) Varian 929-0062 units are used to supply the pumps that evacuate klystrons. The information on the operating current is taken in the form of an analog signal with an amplitude of 0–100 mV.

(2) In the future, it is planned to substitute all Varian 929-0172 units with splitters for high-end Agilent 4UHV, each supplying up to four pumps. The remote control and monitoring of these units can be executed via the RS-485 and Profibus.

3.1.2. Vacuum gages. Pfeiffer TPG 300 and Balzers TPG 300 vacuum gages, which are similar, are used. The vacuum monitoring is performed through the analog leads at the CP300 cards; the signal amplitude is 0–10 V.

3.1.3. Control mechanism. The evacuating system will be controlled based on the B&R equipment. The programmable logic controller (PLC) series X20 will be installed in a control room, and every accelerating station will be supplied with a set of modules equipped with the required number of analog inputs to work with vacuum gages and power units that were used with the MEA pumps. In addition, the necessary number of digital inputs and outputs will be stipulated to control the isolation valves subsystem that is presently at the design stage. The new Agilent 4UHV pump control units will be included in the control system through the Profibus network by the corresponding module in the PLC.

3.2. Magnet System

The information on magnets of the accelerator is summarized in Table 1. Bending dipole magnets for user beam extraction are not included in the table; their parameters will be determined after their calculation.

The basic controlled objects are steering, quadrupole and dipole magnets. All other magnets operate with fixed parameters, and no remote control is provided for them. There are two approaches considered for controlling the correctors and quadrupoles:

(1) Using the current power supplies (Korad KA6003P and KA3005P) that have USB and RS-232 interfaces. Consequently, RS-232 to RS-485 adapters are to be acquired. An option of hubs that would allow connecting several RS-232 or RS-485 devices on the Ethernet is also considered.

(2) The acquisition of new sources with the capability of control on the Ethernet. The basic models considered at the moment are Aktakom APS-7306L, OWON ODP3063, and Korad KWR103.

3.3. Synchronization System

The current synchronization system is based on the CAMAC design, which will eventually lead to increasing potential problems if any unit fails. In this regard, a new system is needed based on high-end equipment with a possibility of setting the synchronizing pulse duration and its delay in respect to the master pulse; the system should have a modular design and, if possible, it should not require the development of software for connecting to the global Tango system. Some versions are being considered and right now a similar system version developed at the JINR for NICA collider appears to be the most promising.

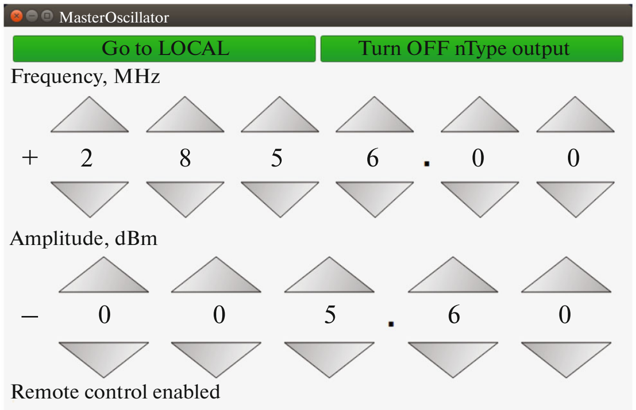

Fig. 1. Client application for the AKIP-7SG384 master oscillator.

3.4. Other Systems

(1) The hardware of the **electron gun** control system [4] will not be modified; as for the software, an appropriate device class for including to the Tango-based global control system will be written instead of the GunCtrl operator program.

(2) It is planned to substitute the available stations of the **thermal stabilization system** for the industrial grade equipment from Huber [5]. The final decision on the procedure of their connection to the global control system will be made after the thermal stabilization module is chosen.

(3) All elements of the **microwave system**—AKIP-7SG384 master oscillator, DIALTEK UMP-245-300 preamplifier [6], and Red Pitaya STEMlab 125-14 data-acquisition boards—interact with the control system on the Ethernet and corresponding classes of Tango devices.

(4) The **accelerating system** is controlled by Weltek controllers [7], which interact with the top level of the control system via RS-485 using the Modbus RTU protocol.

4. TANGO-BASED CONTROL SYSTEM

C++ was chosen as the basic language for writing both server and client applications of the control system with the purpose of formalizing the code (and, hence, simplifying the debugging process) and improving efficiency. Consequently, QTango [8] was chosen among several tools intended for constructing client applications. This is a framework based on C++/Qt. A device class and QTango client were developed (Fig. 1) to control the AKIP-7SG384 master oscillator.

4.1. Radiation Control System

Software compatible with Tango was developed instead of the available standalone software [9]. The basic elements are the demon and the Tango server, which interact using standard tools of interprocess communications of the Linux OS. The demon is required to provide an option of the system standalone operation to improve its reliability; it is responsible for interacting with detectors, translating readings received from gamma detectors from count into dose, importing readings to the archive database, and keeping the file of shared memory from which the Tango server takes data updated. The detector configuration is modified by the corresponding command sent to the demon via the Linux message queue. The system schematic layout is presented in Fig. 2.

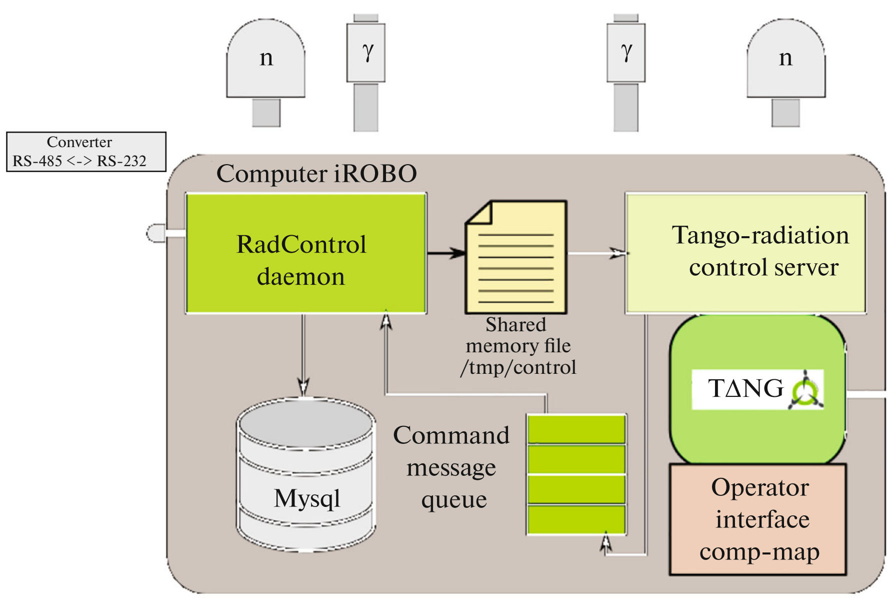

Fig. 2. Schematic layout of the upgraded radiation control system.

The "RCS computer on" status signal for the existing interlock system [9] is arranged by the programmed relay, and the "doors closed" and "key in the socket" signals are read from the interlock system [10].

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