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TANGO STANDARD SOFTWARE TO CONTROL THE NUCLOTRON BEAM SLOW EXTRACTION

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TANGO Controls is a basis of the NICA control system. The report describes the software which integrates the Nuclotron beam slow extraction subsystem into the TANGO system of NICA. Objects of control are power supplies for resonance lenses. The software consists of the subsystem device server, remote client and web-module for viewing the subsystem data.

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BEAM SLOW EXTRACTION FROM THE NUCLOTRON

The superconducting synchrotron Nuclotron is an operating part of the NICA facility which is being constructed at JINR [1].

The beam extraction process from the Nuclotron is realized by excitation of the radial betatron oscillation resonance [2]. The sextupole nonlinearity is excited with two pairs of extraction sextupole lenses (ES). Four fast extraction quadrupole lenses (EQ) are used to reach the resonance frequency performing the coherent tune shift ΔQx within the resonance band.

The beam is extracted directly by means of an electrostatic septum and a two-section Lambertson magnet placed in long drift spaces. The timing chart of the extraction process is shown in Fig. 1. There you can see waveforms of the current in the extraction quadrupole and sextupole windings.

HARDWARE STRUCTURE OF THE SLOW EXTRACTION CONTROL

The current sources “104” and “105” are used to supply the pairs of sextupole lenses. They are controlled by the volt reference signal. The sources convert this signal to a current waveform to supply the lenses. The form of the current supplied to the sextupole windings is an isosceles trapezium.

The quadrupole lenses are supplied with PS260 current source which is also controlled by means of the volt reference signal. In addition, it is possible to control this source and

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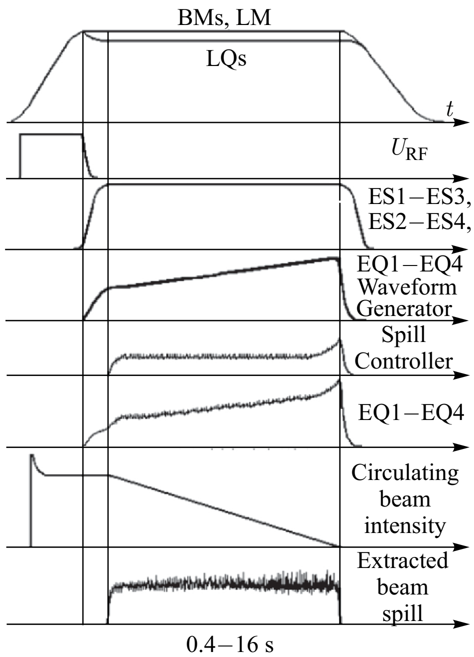

Fig. 1. Slow extraction chart

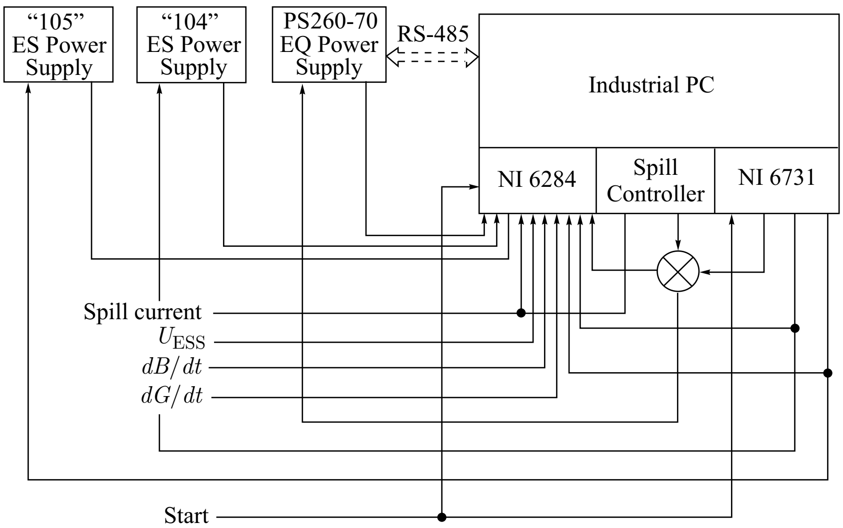

Fig. 2. Hardware diagram of the Beam Slow Extraction Control

monitor its state remotely via RS-485. The waveform of the current to supply the quadrupoles is more complex than for the sextupole ones. It consists of two linear ascending segments and the descending one. Also the feedback signal is added to the basic one to realize the constant-current-beam spill and suppress the low-frequency spill structure.

As you can see in Fig. 2, the basic signals for the current sources are generated by NI 6731 — a four-channel analog output device made by National Instruments. The additional feedback signal for the quadrupole current source is produced by the designed specialized spill controller.

The volt reference and source answer signals as well as spill current and time derivatives of the main magnetic field and its gradient are digitized by NI 6284, the sixteen-channel data acquisition module.

The operation of the input/output modules starts with the "Beginning of the Field Flattop" ("Start") signal. At the end of operation the output module can get new images of the reference waveforms if the operator has changed their settings. And the input module transmits the data acquired to the subsystem computer. Then again, the modules go into the start signal waiting mode. Changes of the spill controller settings and PS260 source status are carried out independently of the accelerator cycle.

TANGO CONTROLS

TANGO [3] is a base of the NICA control system. It is a modern control system framework based on CORBA which has been actively developed in European accelerator organizations, such as ESRF, Alba, Soleil and others, during the last ten years. It is a free open source software which is available on Linux and Windows.

The "Device" is the core concept of TANGO. Device can represent the equipment (for example, analog I/O board), a set of instruments, a set of software functions and a group of devices (subsystem). Device has an interface composed of commands, attributes and properties which provide the service of an instrument. Device Server is a process in which Device is generated and managed.

TANGO control systems are organized hierarchically (or logically). At the lower level we will find elementary devices which are associated with equipment. At higher levels the devices are "logical". These devices, based on the lower-level devices, manage and represent a subset of the control system (or subsystem).

SLOW EXTRACTION DEVICE SERVER

The main module of the slow extraction control software is a subsystem device server which is actually a shell of a group of the equipment mentioned above with the high-level control. The subsystem device server is managing the operation of the low-level device servers associated with analog input/output boards, status module of PS260 current source and the spill controller. The PSMBus device server associated with PS260 status control, in its turn, uses the Serial device server which operates with serial interfaces (see Fig. 3). The high-level device servers interact with the low-level ones by means of DeviceProxy class instances. This class is one of the TANGO API main elements.

The subsystem device server organizes a working cycle of the subsystem and allows the operator to change its settings and get the access to the data acquired via TANGO interface.

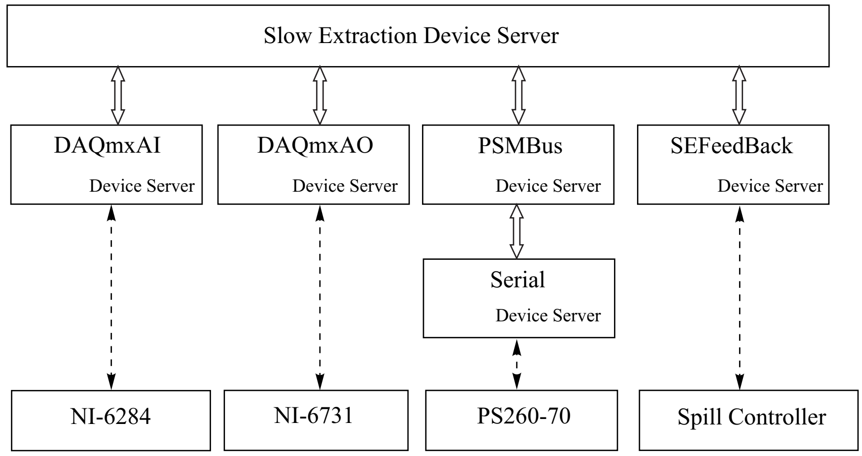

Fig. 3. Diagram of the equipment control by the Slow Extraction Device Server

The TANGO device classes of the subsystem and equipment were developed by means of POGO application [4] which is a standard tool of TANGO Controls.

The table shows the interface of the subsystem device server where you can see three groups of its attributes. The first one determines the basic signal parameters for the resonance lens current sources. The second group is the spill controller settings. And the third attribute group refers to the data acquired by the subsystem.

Attributes of the Slow Extraction Device Server

ResLenses Class Attributes					
Name	**Attr. type**	**R/W type**	**Data type**	**Level**	**Description**
ILQ1	Scalar	READ_WRITE	Tango::DEV_DOUBLE	OPERATOR	The first top point of quadrupoles signal (A)
ILQ2	Scalar	READ_WRITE	Tango::DEV_DOUBLE	OPERATOR	The second top point of quadrupoles signal (A)
ILS26	Scalar	READ_WRITE	Tango::DEV_DOUBLE	OPERATOR	The top value of sextupole pair (2-6) signal (A)
ILS48	Scalar	READ_WRITE	Tango::DEV_DOUBLE	OPERATOR	The top value of sextupole pair (4-8) signal (A)
Plato	Scalar	READ_WRITE	Tango::DEV_USHORT	OPERATOR	Signal plato duration (ms for short mode, s for longmode)
Samples	Scalar	READ	Tango::DEV_USHORT	OPERATOR	Samples per channel (measured signals)
FBReference	Scalar	READ_WRITE	Tango::DEV_DOUBLE	OPERATOR	Feedback module` reference (0..1)
FBCompar	Scalar	READ_WRITE	Tango::DEV_DOUBLE	OPERATOR	Feedback module` comparator value
FBIntegr	Scalar	READ_WRITE	Tango::DEV_DOUBLE	OPERATOR	Feedback module` integrator value
FBCurrent	Scalar	READ_WRITE	Tango::DEV_DOUBLE	OPERATOR	Feedback module` spill current value (0..1)
FBK1	Scalar	READ_WRITE	Tango::DEV_DOUBLE	OPERATOR	Feedback module` K1 value (0...1)
FBK2	Scalar	READ_WRITE	Tango::DEV_DOUBLE	OPERATOR	Feedback module` K2 value (0...1)
FBDiffer	Scalar	READ_WRITE	Tango::DEV_DOUBLE	OPERATOR	Feedback module` differentiator value (0...1)
FBProport	Scalar	READ_WRITE	Tango::DEV_DOUBLE	OPERATOR	Feedback module` proportional channel value (0...1)
FBRecept	Scalar	READ_WRITE	Tango::DEV_USHORT	OPERATOR	Feedback module` receptivness value (0...1)
Meas_Timestamp	Scalar	READ	Tango::DEV_DOUBLE	OPERATOR	The timestamp of the signals measurement
CurWaves	Spectrum	READ	Tango::DEV_DOUBLE	OPERATOR	Chain of measured signals

BEAM SLOW EXTRACTION CLIENT

The subsystem client allows the operator to control the beam extraction process. The client connects the subsystem device server by means of the DeviceProxy class instance, too. The application displays graphs of the captured signals, subsystem parameters, and settings which can be changed by the operator. The Fast Fourier Transform of the captured signal is available. It is necessary to damp the beam spill ripple.

The client allows the operator to read and write subsystem settings and captured signals to the MySql database of the TANGO Controls system. The DeviceProxy instance is also needed to use this database.

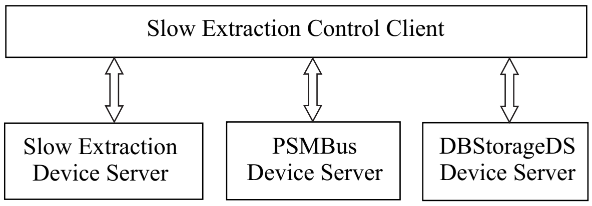

Fig. 4. Interconnection diagram of the Slow Extraction Control Client

Except for the subsystem device server the client directly connects the PSMBus device server (see Fig. 4). It allows one to control the PS260 current source without activating other parts of the subsystem during adjustment of this source.

The staff members can starts the client application at any authorized workstation only in the monitoring mode.

BEAM SLOW EXTRACTION WEB-CLIENT

We use the WebSocketDS device server to display graphs of the captured signals in the Web (see Fig. 5). This device server receives the necessary data from the subsystem device server, packs them into the JSON [5] object and sends it to all browsers connected to it via WebSocket protocol [6].

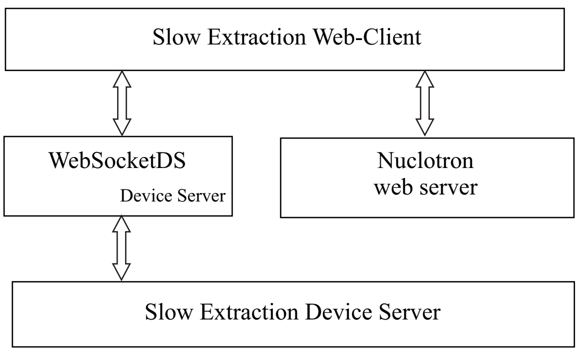

Fig. 5. Interconnection diagram of the Slow Extraction Control Web-Client

CONCLUSIONS

Now the Slow Extraction Control Subsystem of the Nuclotron has a TANGO interface. The TANGO standard software for the subsystem consists of the high-level subsystem device server and several low-level device servers assigned to the equipment modules and client applications. The software was tested during the latest Nuclotron run and thereafter. All the detected bugs have been fixed. The software is ready to be tested at the next run of the Nuclotron.

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