Upgrade of the Nuclotron Injection Control and Diagnostics System.

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INTRODUCTION

The Nuclotron is a 6 GeV/u superconducting synchrotron operating at JINR, Dubna since 1993. It will be the core of the future accelerating complex NICA which is under development now. The report presents details of the Nuclotron injection hardware and software upgrade to operate under future NICA control system based on Tango. The designed system provides control and synchronization of electrostatic and magnetic inflector devices and diagnostics of the ion beam injected from 20MeV linear accelerator to the Nuclotron.

INJECTION SYSTEM LAYOUT

The one-turn injection scheme layout consists of two main elements: superconducting septum magnet and electrostatic kicker.

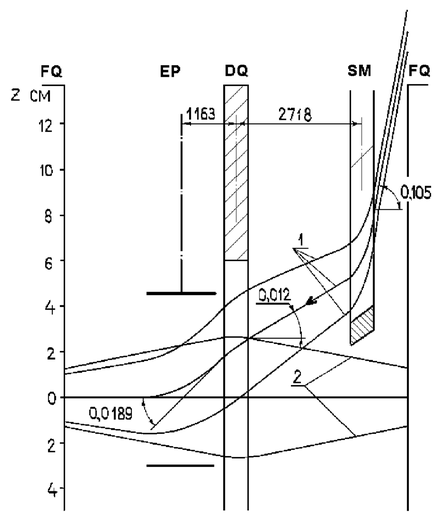

Figure 1. Injection layout

Table 1: Requirements:

1. Nonlinearity of electric field in the working area	< 1%
2. Voltage on the plates	(40+0.4)kV
3. Discharge time	<100 nsec
4. Rest voltage for 1 msec after discharge	<2%
5. Total capacity of the potential plate relative to ground	280pF
6. Total inductance	0.4 µH
7. Wave impedance	37.8 Ohm

The superconducting septum magnet is supplied by the direct current power supply EVPU PS140-8S and permanently deflects heavy ion beam in the vertical plane.

The electrostatic kicker is working in cycle:

- HV power supply Spellman SL60P300 apply 40kV between the electrostatic plates before injection;
- After injection, right before the beam completes its first turn (duration is about 8 µs) the power supply is immediately and the thyratron of TGI1-2500/50 type is switched on in the short period of time. A special circuit keeps thyratron fired during acceleration cycle to decrease voltage between plates.
- When the cycle of acceleration is completed the thyratron is turned off.
- The control signals timing can be adjusted with 10 ns accuracy by using 32-bit counters clocked with 100 MHz signal.

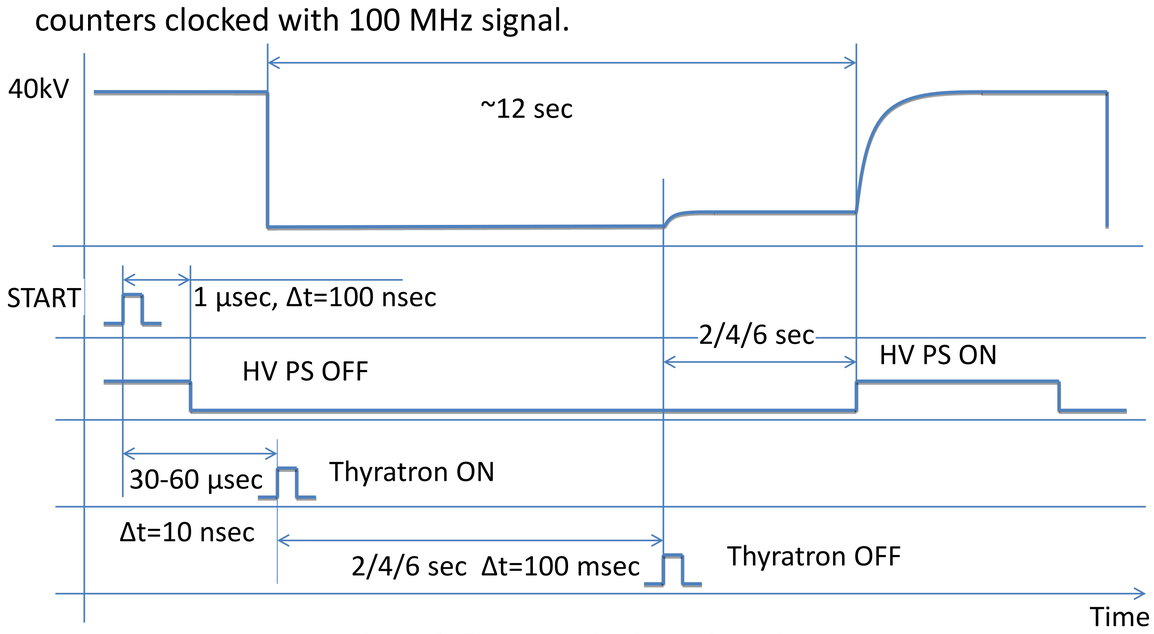

Figure 2: Electrostatic kicker time diagram.

INJECTION SYTEM STRUCTURE

The control equipment is located in the electronics room of the Nuclotron building:

- industrial PC;
- controller based on Atmel AVR MEGA128 microcontroller and a complex programmable logic device (CPLD) Altera Max II;
- NI acquisition boards USB-6259 and digitizer NI PCI-5105.

The power part of the equipment located in Nuclotron building and tunnel:

- HV power supply Spellman SL60P300;
- septum magnet power supply EVPU PS140-8S;
- thyratron modulator, keep-alive circuit and control units.

CONCLUSIONS

The upgraded Nuclotron injection control and diagnostics system was put into operation during the 47 run of Nuclotron in March 2013. It has demonstrated high reliability, operation convenience and fulfilled the injected beam quality requirements. The software implementation using TANGO framework allowed to reduce the development time significantly and confirmed the usage of TANGO concept as a basis for the future NICA control system.

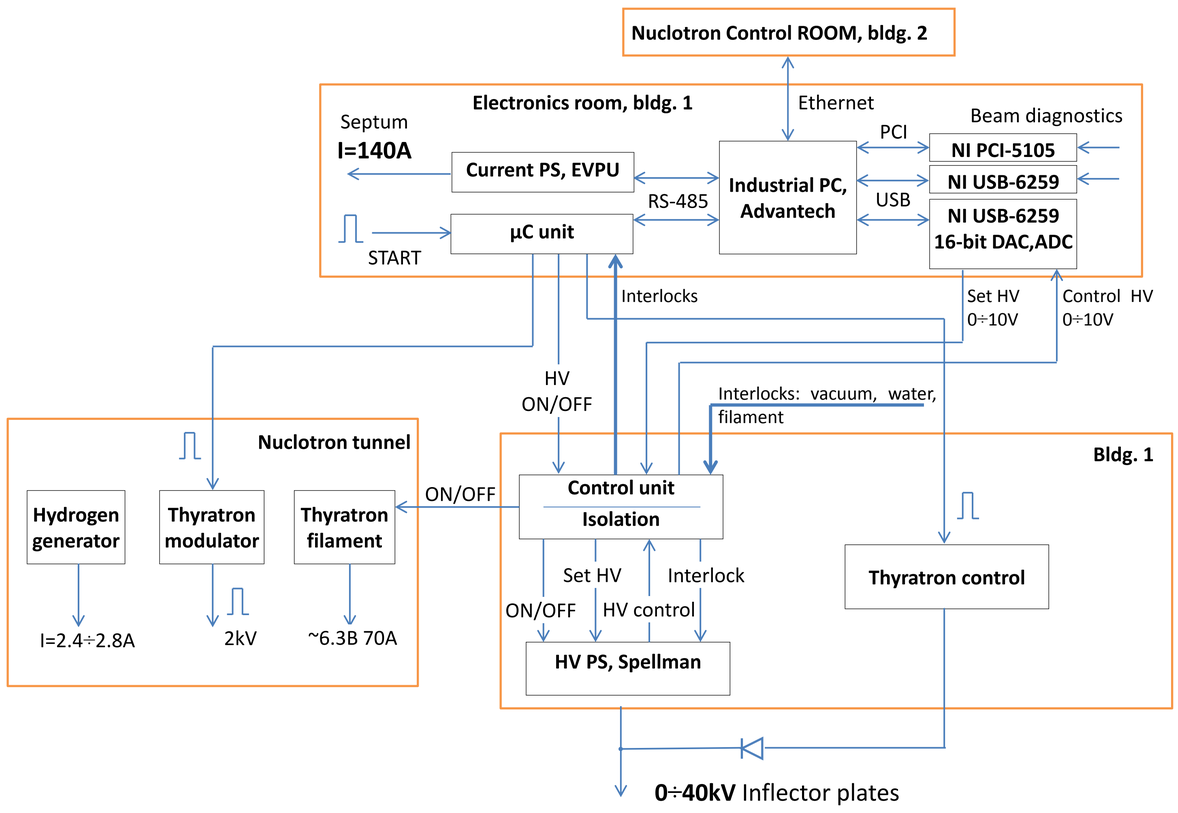

Figure3: Injection control and diagnostics system structure

SOFTWARE COMPLEX

The software part of injection control and diagnostics system is implemented using Tango that is accepted as the future NICA accelerating complex control system base. The software developed for the injection control system consists of:

- The controller firmware including C program for the Atmel AVR microcontroller and VHDL code for the Altera CPLD – client Modbus protocol implementation, interlocks handling and digital signal generation with 10 ns accuracy up to 1000s duration.
- Tango device servers implementing fieldbus communication protocols Modbus/RTU and Profibus.
- A Tango device server to control the EVPU PS140-8S power supply (utilizing Profibus Tango device) – setting and controlling the superconducting septum magnet current with slow increase and decrease and error processing.
- A Tango device server to communicate with the intelligent controller (utilizing Modbus Tango device) – obtaining and resetting alarms, adjusting the signals delays according to the accelerating cycle duration.
- Tango device servers to operate NI acquisition devices based on the NI-DAQmx drivers – analog input and output, digital input and output, time measurements and pulse generation using counters.
- Tango device servers to control NI digitizers using the NI-SCOPE drivers – multichannel acquisition with desired sampling frequency and number of samples.
- Tango device servers to control NI digital multimeters using the NI-DMM drivers – static voltage and current measurements with high accuracy.
- High-level Tango device servers implementing injection control algorithm and beam diagnostics. They control low-level tango devices, acquire data from them and convert the data to physical quantities.
- Client applications developed in the NI LabVIEW environment using LabVIEW Tango bindings. The client applications communicate with high-level Tango devices using events and only implement the operator interface and data visualization. The control algorithm is realized in high-level Tango devices.

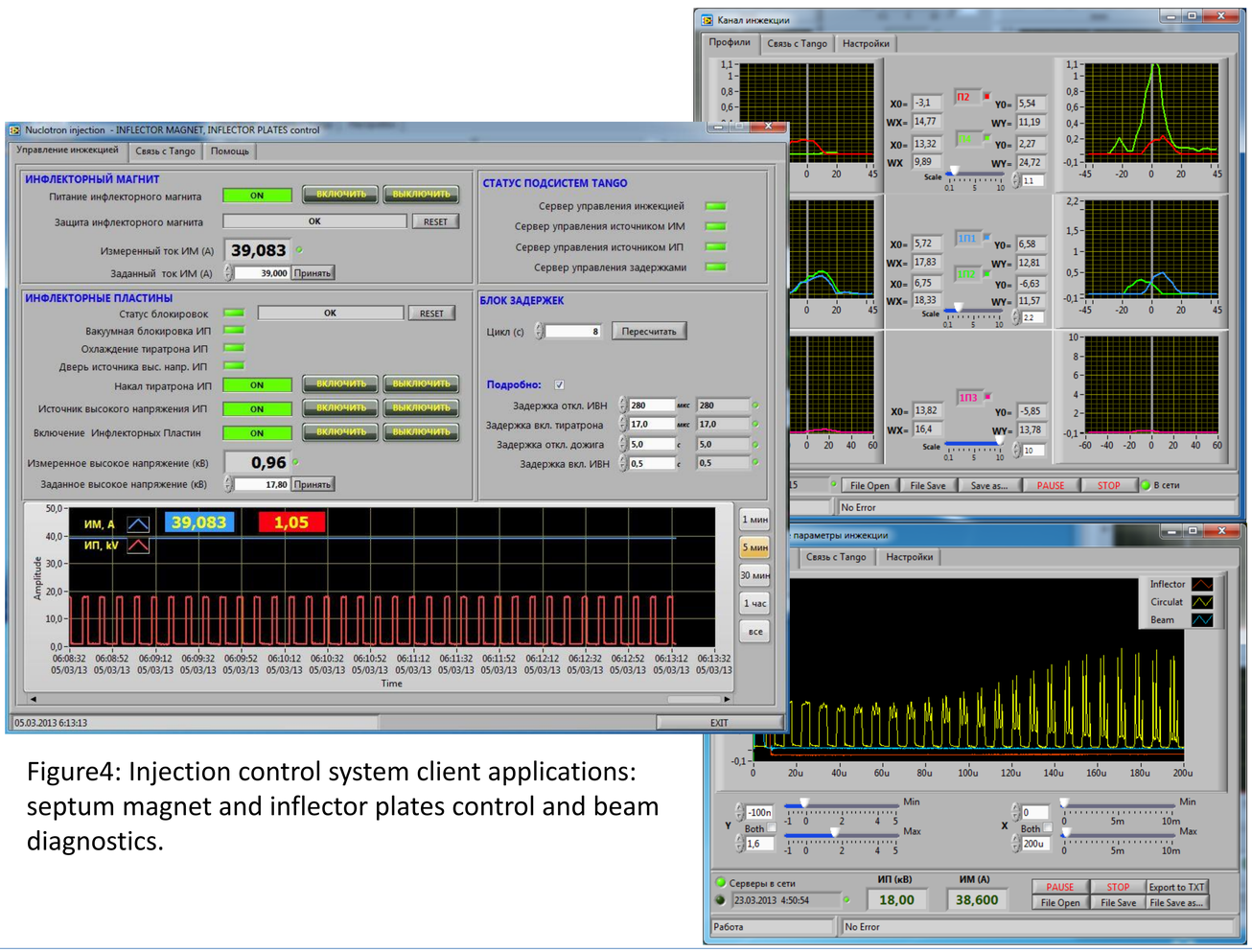

Figure4: Injection control system client applications: septum magnet and inflector plates control and beam diagnostics.