THE UPGRADED CORRECTOR CONTROL SUBSYSTEM FOR THE NUCLOTRON MAIN MAGNETIC FIELD

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Abstract

This report discusses a control subsystem of 40 main magnetic field correctors which is a part of the superconducting synchrotron Nuclotron Control System (NCS). The subsystem is used in static and dynamic (in dependence of the magnetic field value) modes. Development of the subsystem is performed within the bounds of the Nuclotron-NICA project.

Principles of digital (PROFIBUS-FLNR RS-485 protocol) and analog control of the correctors' power supplies, current monitoring, remote control of the subsystem via IP network, are also presented. The first results of the subsystem commissioning are given.

INTRODUCTION

The superconducting synchrotron Nuclotron [1] is one of the JINR basic facilities. It is intended to produce beams of charged ions (nuclei), protons and polarized deuterons with energies up to 6 GeV per nucleon.

The existing magnetic structure of the Nuclotron consists of 8 superperiods. Each superperiod includes 3 Regular FODO-periods and 1 period with a long drift space between the lenses. A regular FODO-period consists of one focusing and one defocusing quadrupole lenses each 0.45 m long, four dipole magnets each 1.5 m long and two free spaces for multipole correctors and diagnostics equipment placement. A long drift space is occupied by injection and extraction magnets, the internal target and etc.

The particle orbit is deformed in the real magnetic structure because of various kinds of perturbations which affect negatively on the accelerator complex operation. The orbit correction system (OCS) brings compensative perturbations of the same kind in the magnetic structure of the accelerator. The purpose of the OCS is to correct the equilibrium orbit and provide its stable position during acceleration process.The system consists of 40 correcting multipole superconducting magnets (21 horizontal and 19 vertical).

The control subsystem of the OCS is integrated to the Nuclotron Control System [2]. It gives the accelerator operators the opportunity of wide and flexible control of the correction system from the OCS console as well as from any authorized workstation of the Nuclotron LAN [3].

THE CONTROL SUBSYSTEM STRUCTURE

The common structure of the corrector control subsystem is illustrated in Fig. 1.

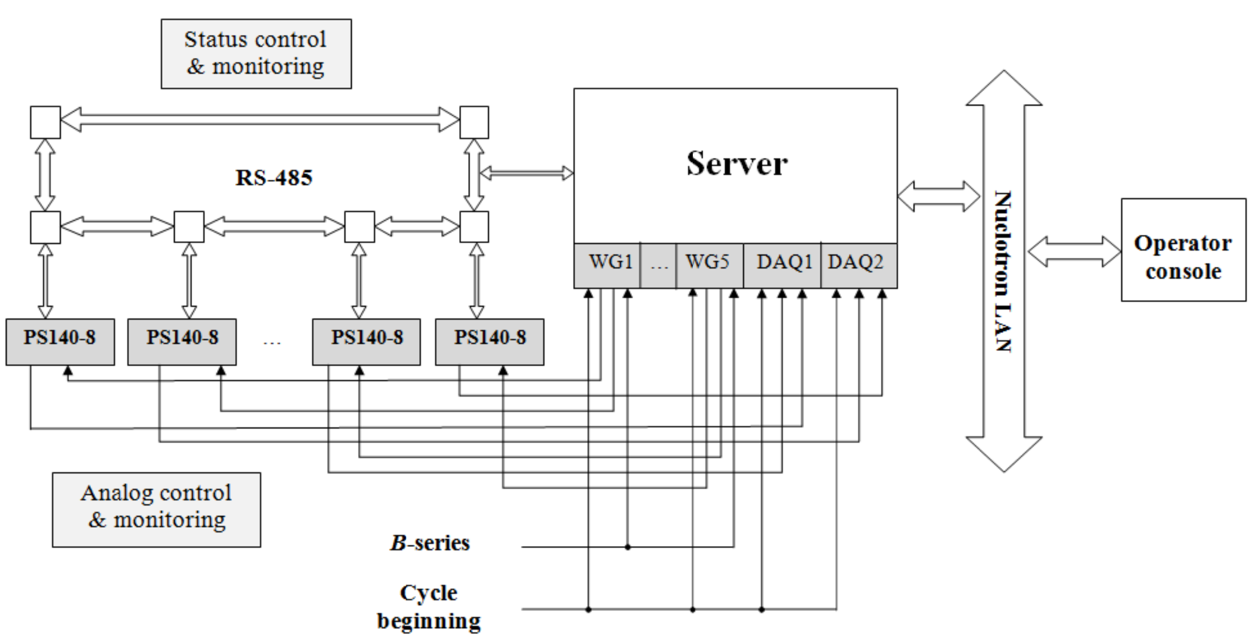

Figure 1: The control subsystem structure scheme. WG means waveform generator, DAQ – data acquisition board.

Power Supplies

The correcting multipoles are supplied by PS140-8 – the sources of current which were specially designed to supply electromagnetic elements of accelerators by «EVPÚ a.s.» (Slovakia). These sources replaced the out-of-date previous ones which had the insufficient output current range and stability. The PS140-8 power supply is a transistor converter serving as a source of DC current for R-L load with high stability of time and thermal conditions. The output current is regulated within the range of 0 to 140 A by a corresponding input signal between 0 and 10 V. The power supplies can work in a static mode as well as in a dynamic one with the current change rate from 0 to 100 A/s.

As it is mentioned above the PS140-8 output current can be controlled remotely by the external voltage reference signal. Such commands as load switching on and off, checking of the power supply status, changing of the load current direction and so on, can be carried out remotely via communication channel RS-485 (protocol – PROFIBUS-FLNR).

The Subsystem Server

The main part of the control subsystem is a rack-mounted industrial PC. It performs all interactions with power supplies such as generation of reference signals, monitoring of the power supply output current and status controlling. The server also provides the remote control of the subsystem via IP-Network (see The Control Subsystem Software section below).

Waveform Generators

To produce a reference signal of the output current we have used five National Instruments NI6733 PCI boards installed in the server backplane. These boards provide eight 16-bit resolution analog output channels with the update rate up to 1 MS/s. As it is mentioned above there are two modes of the correction system operation: static and dynamic. In the static mode the output power supply current is permanent during acceleration. If it is necessary to change the output current value the NI6733 module generates the corresponding gradual transition of the voltage. In the dynamic mode the power supply current depends on the instant value of the main magnetic field. So the image of this relation function is written to the waveform generator memory. The Nuclotron B-timer is used as an external clock source for the NI6733. Every B-timer pulse corresponds to magnetic field changing by 10^{-4} T (repetition rate is up to 10kHz).Also the module is triggered by a digital signal of "acceleration cycle beginning" in this case.

Data Acquisition Modules

For monitoring of the power supply output current two National Instruments NI628433 PCI boards are used. These modules are also installed in the subsystem server backplane. The NI6284 DAQ board provides 32/16 single-ended/differential analog input channel with an 18-bit resolution. In the dynamic mode these modules are triggered by the "acceleration cycle beginning" pulse as well as waveform generators. In the static mode DAQ boards work continuously writing the acquired waveforms to the server memory every 4 seconds.

RS-485 Communications

For status operations the subsystem server interacts with PS140-8 via RS-485 interface forming a ring topology. This communication runs on 115200 baud speed. The MOXA CP-132 PCI board provides a RS-485 interface on the server side. Power supplies are grouped on ten boxes placed along the accelerator ring. Links between the boxes are made with multi-mode fiber optics. The conversion between the fiber and serial interfaces is provided by the MOXA TCF-142-M module.

Network and Remote Station

The Nuclotron Control Room is placed 400m away from the accelerator hall where the power supplies and subsystem server are located. So it is necessary to have a remote control of the subsystem. The remote control is carried out via 1 GbE Nuclotron LAN (which is a subnet of the LHEP/JINR network). The operator can access the subsystem server from any authorized workstation connected to the LAN and running the special developed client software.

THE CONTROL SUBSYSTEM SOFTWARE

The software complex of the OCS control subsystem consists of two parts: application running on the subsystem server and client application running on operator workstations.

Server Software

The application running on the server computer performs the following main tasks: power supply status control, power supply output current setting and monitoring, data presentation and remote control providing.

To monitor the state of the PS140-8, the server starts separate thread for scanning all the power supplies in a specified address range along the RS-485 network. The thread requests the detailed status from every detected power supply and displays it on the corresponding panels of the server GUI (see Fig. 2).

One can see that the operator can give a command to power supplies to turn the load on and off, change the output current polarity and reset the error signal. It is also possible to set the output current value (in the dynamic mode it means that the current corresponds to the main magnetic field at the beam injection level). It should be noted that the waveform generators produce a reference signal for the power supply only if its load is on.

The acquired waveforms of the power supply output current may be displayed in the assembled diagram on the server application form (see Fig. 3).

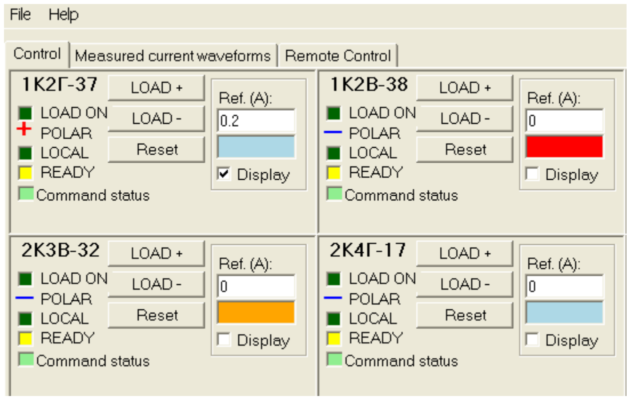

Figure 2: The PS140-8 control panels.

For the remote control realization the server starts another separate thread. It listens, checks and serves the incoming connection from the operator workstation. Any information acquired from power supply is sent to the remote client immediately.

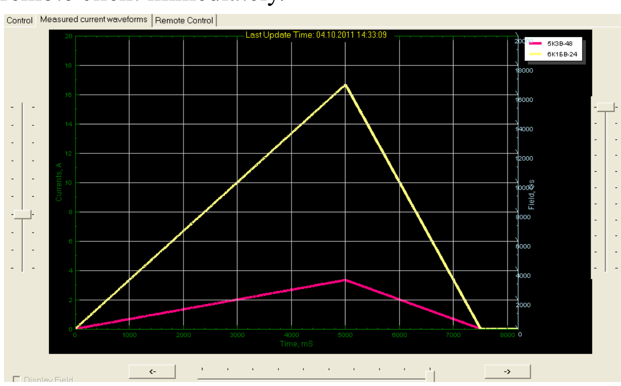

Figure 3: The assembled diagram of the acquired current waveforms.

Remote Client software

The main conception of the subsystem remote control is that the authorized user can operate corrector power supplies from the remote station just the same way as from the subsystem server console. The remote client application interface is practically identical with the server one. The server supports only one remote connection simultaneously to maintain the operation consistency. Communication between the server and remote client applications is carried out by the socket technology. The Client and Server were both developed for the .NET Framework.

FIRST RESULTS OF THE SUBSYSTEM EXPLOITATION

The new corrector control subsystem was put into operation in November, 2010. During the two latest Nuclotron runs it worked in the static mode. The subsystem has proved to be an effective instrument of the accelerator tuning. As a result of the modernized OCS exploitation the intensity of the deuteron beam (accelerated to the energy corresponding to the main magnetic field - 0.2 T) reached $5{\cdot}10^{10}$ particles [4]. It is planned to use the OCS in dynamic mode during the next Nuclotron run (November-December, 2011).

At the moment the development of the project NICA (Nuclotron based Ion Collider fAcility) [5] is carried out at JINR. The experience of the corrector control subsystem construction can be used in another part of the NICA complex – a superconducting Booster [6].

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