DEVELOPMENT OF HARDWARE AND SOFTWARE PRODUCTS OF SLOW-EXTRACTION SYSTEM BY MEANS OF CRYSTALLINE DEFLECTORS ON SYNCHROTRON U-70

S. Reshetnikov, A. Afonin, E. Barnov, A. Levin, M. Ukhanov,
Institute for High Energy Physics (IHEP) of "Kurchatov Institute",
142281 Protvino, Moscow Region, Russia

Abstract

S. Reshetnikov et al. The review is devoted to hardware and software products developed to serve working complex of extraction system by means of crystalline deflectors on the synchrotron U-70 IHEP.

INTRODUCTION

The system of high energy charged-particle beam's slow-extraction by means of crystalline deflectors (hereafter referred to as a "System") constitutes a part of IHEP synchrotron U-70 extraction system.

The slow-extraction by means of crystalline deflector has a number of strong points, which makes it popular with a number of physical units [1]. Practical implementation of this injection mode in IHEP synchrotron set up in 1997 and was based on baseline design of crystalline deflectors' stations and their control systems. To meet demands in new physical experiments, the development of managements systems of crystalline deflectors' stations for a long period was based on technical solutions previously adopted and slightly improved.

By today's standards, the system is obsolete and worn-out. New approaches and innovative solutions are required for maintenance, management and further development. This investigation reports on baseline design (pilot model) of crystalline deflectors' station, upon which the modernization of the System is planned.

THE UPGRADED CRISTALLINE DEFLECTORS' STATION

There are 11 varied crystalline deflectors' stations (hereafter referred to as CDS) now in the synchrotron U-70, which are operated by a number of control systems.

We worked out an advanced CDS.

For horizontal and angular movement we affirmed a unique type of stepper motor FL39ST38 manufactured by "Electroprivod"[2]. The engine rig tests confirmed that the power performance of the motor ensures mechanical operation of upgraded CDS.

Here are some of technical characteristics of upgraded CDS:

1. Radial and horizontal carriage drives - stepper motor FL39ST38- 0504A. Phase current I = 0.5 A; motor torque = 0.29 Nwm.
2. Carriage radial range – 150mm.
3. Cristal angular excursion range – 40 mrad.
4. To measure and to display the radial movements of the carriage and angular excursions of the crystal, varied potentiometers with resistance value of 10 kiloohm are used.
5. Extreme positions of the carriage and the crystal are fixed by microswitches.
6. The CDS is placed in standard vacuum box with inside diameter of 203mm and associated length of 520mm.
7. The electric connection of the CDS to the command equipment is effected by multicore radio-frequency cables.

Here on Figure 1, you may find the first sample of upgraded CDS which is equipped with two carriages. This first model of the upgraded CDS is manufactured by IHEP development design office.

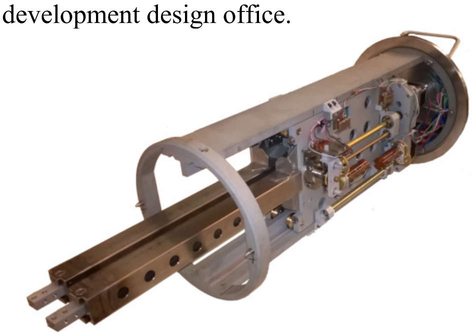

Figure 1: Crystalline deflectors' stations (CDS) with two carriages.

THE CONTROL SYSTEM

The CDS control system developed in IHEP is an entirely automated system. It consists of two functional parts: the **command part** which is located on panel of extraction system (and includes IBM PC), and the **peripheral part** which is located in the tunnel of U-70 close to CDS, where the radiation exposure is considerably less than on the orbit of U-70.

The automated control system (ACS) while managing the CDS, resolves the following tasks:

1. Selection of one of the CDSs, which are placed on synchrotron U-70.
2. Selection of the carrier among those two on the CDS.
3. Parameters of radial and angular movements of the carriage.

ISBN 978-3-95450-197-7

4. Radial and angular coordinates measuring of the crystals.
5. Processing and archiving of the received information.

The Radial and Angular Directional Control

Each carriage with the crystal installed has its limited range of motion. Those extreme positions are limited by microswitches. The movements of the crystal are being continuously reported by position potentiometer. That enables us to locate the crystal at any time and to set a coordinate.

After the operator sets a coordinate, the system places the carriage in the required radial and angular position. The precise location of the carriage is being achieved through adjustment of the coordinate to the potentiometer data. As an extra measure, software constrains the excursion range.

The radial and angular transitions' software serves the following regimes:

1. "Run mode" – passing all range from one end switch to the opposite end switch on the highest speed.
2. "Start point acquisition" – the operator sets the start angle or spanwise coordinate. The speed is the highest.
3. "Step" – this regime enables the operator to move the mechanism with required intervals either angularly or radially.

In actual version positional precision of crystal is of 0,1 mm radially and 15 urad is achieved.

IBM PC with specially designed software is used in control section of ACS of CDS. The PC located in control room interworks with peripheral unit through protocol RS-485. The IBM PC and the peripheral unit are located in accelerator room close to CDS. Data exchange rate is 19200 Baud. Data exchange between IBM PC and peripheral unit proceeds through a simplified version of protocol standard IEC-1107.

The peripheral unit consists of the following modules:

1. Microprocessor module M128-DRV-4.
2. Sigma-Delta ADC module ADC8-24.
3. The drivers' module for four step engines DRV-4M control.
4. Modular power source AC250/24-12-5.
5. Stabilized power source for multiturn adjustable resistor.

The peripheral unit is located outside of vacuum box and is connected to the CDS by multicore radio-frequency cables type. The length of the cables is limited by pointing to signal tracks.

The figure 2 shows the appearance of the control equipment

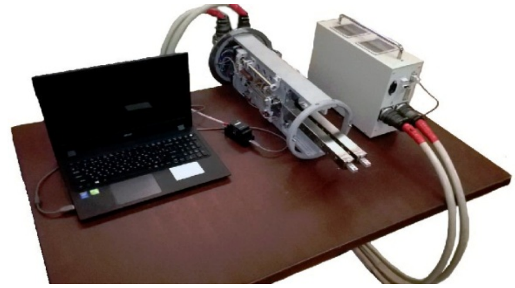

Figure 2: Control equipment (from the left to the right): IBM PC, CDS and peripheral unit on setup (adjustment) stand.

Figure 3 shows the chart relations of elements in a channel of ACS CDS.

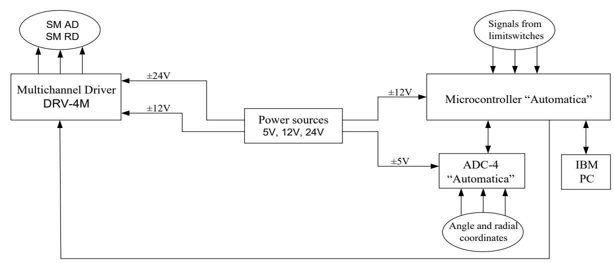

Figure 3: The chart shows relations of elements in a channel of ACS CDS.

THE SOFTWARE

The software consists of two parts: a software controlling CDS (which is executed on microcontroller basis in module M128-DRV-4) and a software at the operator's position (the code of which is executed on IBM PC in the control room). You may find the schematic diagram of microcontroller performance on Figure 4.

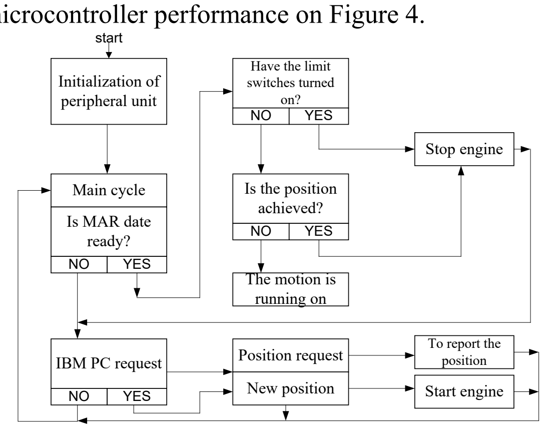

Figure 4: Microcontroller M1128-DRV-4 logic diagram.

The data of the multiturn adjustable resistor are digitized with Sigma-Delta ADC within the accuracy to 16 binary bits. The ADC is being interrogated with a frequency of 78 Hertz. After initialization of peripheral units, the endless loop launches, in which the ADC is being interrogated and availability of the request from the controlling IBM PC is being checked. If the request is

ISBN 978-3-95450-197-7

delivered, the compliant action follows: the engine starts or stops, the coordinates of CDS and the state of limit switches are reported.

As software for controlling IBM PC we adopted the most sustainable and widely used version of Linux/Debian [3]. To implement operator's station we used C++ software language on the basis of Qt widget toolkit.

THE DEVELOPMENT OF ACS OF CDS

The angular unit hardware program is going to be supplemented with Scanning mode. In this mode the operator sets initial and final angle attitudes of the crystal, pulse resolution (i.e. the amount of steps to move from one point to another), and the amount of cycles of accelerator during which the specified angle is to be held.

Each crystal angle attitude will be accompanied by collection and analysis of beam analyzer's data (of accelerated intensity beam, of neutral intensity to the channel by means of crystal). While the scanning, the extraction efficiency variation with crystal orientation angle is being construed and displayed. The ACS in Scanning regime will obtain and analyze the data of magnetic cycle U-70, as well as the data of accelerated beam. In the absence of any signal about the cycle or intensity, the Scanning regime will terminate.

On Figure 5 the functional block diagram shows further development of ACS of CDS in order to manage all available CDSs at U-70.

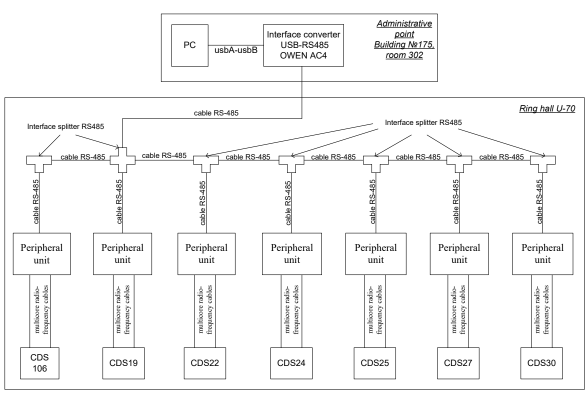

Figure 5: Proposed functional block diagram of ACS of CDS.

CONCLUSION

The testing carried out on synchrotron U-70 in session II of 2016, session I of 2017 and session I of 2018 confirmed reliable operation of hardware and software complex in assembly with advanced CDS and ACS of CDS.

It is confirmed that new complex prevails over the former control system on the following criteria: crystal positional precision is enhanced, process control is significantly accelerated, maintainability is improved, and development opportunities are available (which was impossible with the former control system). Successive templating of our complex will allow renewal of the slow-extraction system by means of crystalline deflectors on synchrotron U-70.

REFERENCE LIST

[1] Afonin A. G., Baranov V. T., Birjukov V. M. at al. Physics of Elementary Particles and Atomic Nuclei, 2005, volume 36, part 1, pages 43-99.

[2] www.electroprivod.ru

[3] https://www.debian.org/