DRIVE SYSTEM CONTROL FOR KOLKATA SUPERCONDUCTING CYCLOTRON EXTRACTION SYSTEM

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Abstract

The K500 Superconducting Cyclotron at VECC, Kolkata uses two electrostatic deflectors, eight passive magnetic channels, one active magnetic channel and two compensating bars as its extraction elements. Except the active magnetic channel, all the other elements can be moved radially, typically by ±6 mm around a centre position. This maneuverability is due to the fact that not all the ions, spanning the operating region of the cyclotron, will have the same optimum beam extraction radius. At the end of the beam extraction channel, the beam is shaped and aligned by a pair of water cooled slit. The slit movement is pneumatically controlled as it has to be operated in high magnetic field. The computer controlled drive system can move the elements precisely. The paper will describe the drive system and its control mechanism.

INTRODUCTION

The extraction system in superconducting cyclotron [1] is required to extract the beam from the cyclotron. The extraction system layout is shown in fig. 1.

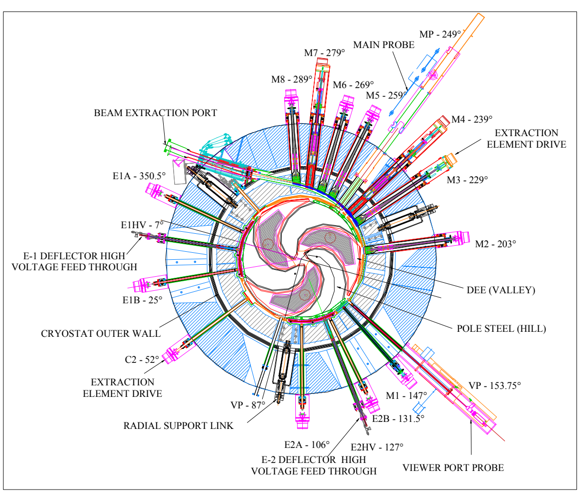

Figure 1: Extraction system layout.

It is inherently difficult to extract beam because of the high magnetic field and small turn separation. The high magnetic field itself exerts a strong centripetal force that has to be encountered to deflect the beam out of the cyclotron [2]. Because of the very restricted space in the cyclotron, the deflectors must be built with utmost care with proper surface finish to achieve a high electric field gradient. After deflecting the beam to suitable radius using electrostatic deflectors (Fig. 2), magnetic devices called magnetic channels (Fig. 3) can complete the task of deflection. Compensating bars have to be judiciously installed to compensate addition of magnetic material due to magnetic channels.

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Figure 2: Electrostatic deflector.

Beam dynamics demand that extraction components viz. electrostatic deflectors, magnetic channels and compensating bars should have accurate movement mechanism.

Figure 3: Magnetic channel.

SYSTEM DESCRIPTION

The magnetic channels are required to be moveable to suit extraction conditions of different beams. The movement mechanism has to be reproducible and precise. The drive

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system (Fig. 4) of a magnetic channel is consisting of a synchronous motor, gears, encoder, a lead screw and nut. The synchronous motor drives a lead screw and nut. The lead screw nut is fixed to the magnetic channel element using a stainless steel tube. At the vacuum barrier, edge welded bellow has been used. The motion of the lead screw is transmitted to an angular encoder, which gives the position of the extraction element.

Figure 4: Motor drive for magnetic channel M4.

General Layout

The layout of the control system is shown in fig. 5. The drive system for the magnetic channel is fully computer controlled. A geared synchronous motor precisely controls the position of the magnetic channel using hardware modules and dedicated HMI software, developed in-house. An absolute encoder is attached to the motor shaft for monitoring the channel position remotely.

The drive system is having the following features:

- All the magnetic channel and compensating bar drives can be operated both manually and remotely from the control console.
- Mechanical limit switches are placed to restrict the movement of the magnetic channels in addition to the predefined software limits.
- The maximum range of travel of the single drive is 15 mm with an accuracy of ±2% of full scale range with a resolution of 0.1 mm.
- Optical encoder is calibrated to provide the actual displacement of the drive. It provides digital output collected by individual electronics with local display developed at VECC. A centralised DAQ server communicates via RS-485 to collect all the position values and send them to the HMI on the console.
- Relays located in the drive control module (Fig. 6) are used for two purposes; firstly, to execute the interlocks for the limit switches and secondly, to facilitate operation of the drives both from locally and remotely through control console.

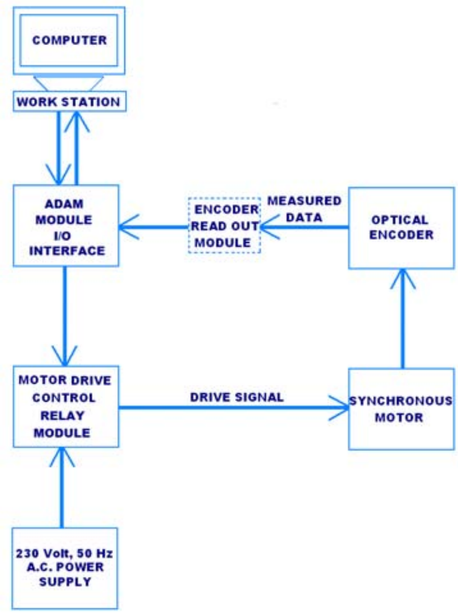

Figure 5: Block diagram of drive system.

Drive Specification

The drive is having the following specification:

- Maximum range: 15 mm for the single drives
- Resolution: 0.1 mm
- Accuracy: ±2% of full scale
- Drive Speed: 1.35 mm/s
- Drive load: 40 Kg

$$V = \frac{P \times S}{R} = \frac{1.5 \times 1.2}{1.33} = 1.35\, mm/s$$

where V (mm/s) is the drive speed, P (mm/rev) is the lead screw pitch of the drive, S (rps) is the motor speed, and R is the gear ratio.

Software

HMI for the drive control system (Fig. 7) is developed using LabVIEW and installed on an industrial computer at central control room. The software communicates with the remote distributed DAQ modules via control LAN. The same software also collects drive position feedback values and beam current values from the encoder data server and beam current server respectively. In case of any communication error, it displays the error in blink mode.

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Figure 7: HMI for the drive control system.

The software takes care of the individual movement of each channel drive in three modes. In the ‘press to run mode’, the user can freely drive the channel between limits. As long as the run button of the particular channel is pressed, the drive runs until it reaches the limiting point. In the ‘preset mode’, user can set a position value and the software does the rest to position the channel within ±0.2 mm of the set value. In the ‘auto set mode’, user can choose a pre assigned data file containing the position value of all the channels and the software takes care of positioning each channel one by one. It displays a message after setting the position. The software can also provide a bird’s eye view of the all the drives with actual positions. It features a protected service mode and an on-screen help for easy explanation of the operational methods, thus providing user friendly environment for reliable operation.

Table 1: Typical accuracy test result performed on Oct 21, 2009*

Drive	Encoder display	Vernier value
E1A	13.4 mm	13.5 mm
E1A	7.1 mm	7.1 mm
E1B	7.1 mm	7.3 mm
M2	9.7 mm	9.7 mm
M2	8.0 mm	7.8 mm
M5	10.6 mm	10.6 mm
M8	10.2 mm	10.14 mm
M8	10.3 mm	10.4 mm

*Some position values could not be measured due to inaccessibility of the drive locations.

CONCLUSIONS

The superconducting cyclotron extraction element drive assembly and its control system are fabricated in-house. The complete control system with associated hardware and software is successfully commissioned in October, 2009 and since then is in continuous operation. At present, this combined instrumentation and control system is running smoothly up to our satisfaction. Efforts are also being made to upgrade some of the field components in accordance with the feedback received from different operators at later stage.

Figure 6: Internal & external view of the control module.

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