Drive System Control for Kolkata Superconducting Cyclotron Extraction System

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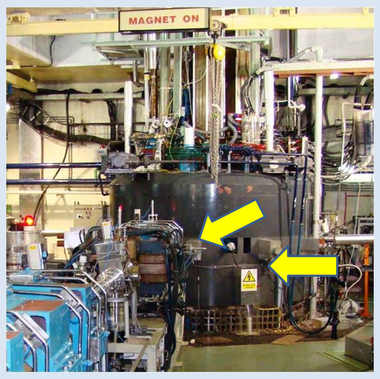
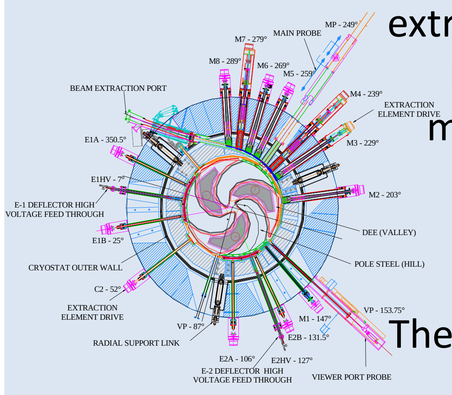
Why drive control?

The K500 Super-conducting 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. The 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.

What is to be driven?

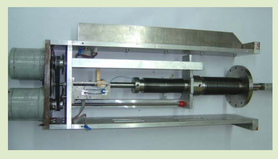
It is inherently difficult to extract beam because of the high magnetic field and small turn separation.

The high magnetic field itself exerts a strong centripetal force that has to be encountered to deflect the beam out of the cyclotron.

After deflecting the beam to suitable radius using electrostatic deflectors, magnetic devices called magnetic channels can complete the task of deflection. Compensating bars have to be judiciously installed to compensate addition of magnetic material due to magnetic channels.

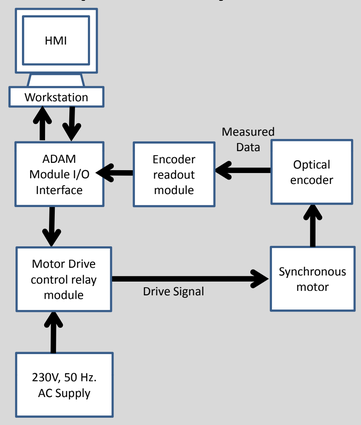
System description

The drive system 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. The motion of the lead screw is transmitted to an angular encoder, which gives the position of the extraction element.



General Layout

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 for the magnetic channel is fully computer controlled.



Salient features

The drive system is having the following features:

- All the magnetic channel and compensating bar drives can be operated both manually & 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 to the HMI.
- Relays in the drive control module are used firstly, to execute the interlocks for the limit switches & secondly, to facilitate operation of the drives both from locally & remotely through control console.

Drive specification and accuracy data

Max. 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

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

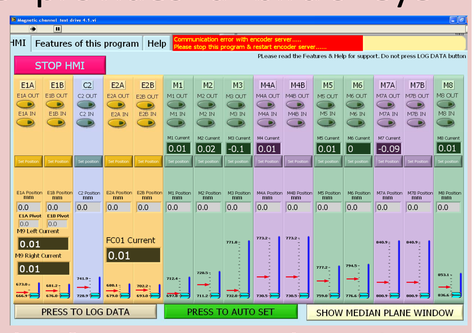
[V (mm/s) is the drive speed, P (mm/rev) is the lead screw pitch of the drive, S (rps) is the motor speed, and R is the gear ratio.]

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

Software

HMI for the drive control system 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. It also collects drive position feedback values & beam current values from the encoder data server & beam current server respectively. In case of any communication error, it displays the error in blink mode.
- The software takes care of the individual movement of each channel drive in 3 modes.
  1. 'Press to run mode', to freely drive the channel between limits.
  2. 'Preset mode', to set a position value and the software does the rest.
  3. 'Auto set mode', to choose a pre assigned data file containing the position value of all the channels.
- The software provides a bird's eye view of all the drives & real positions. It features a protected service mode & on-screen help for easy explanation of the operational methods, thus providing user friendly environment for reliable operation.



Final words

The superconducting cyclotron extraction element drive assembly & its control system are fabricated in-house. The complete control system with associated hardware & software is successfully commissioned in Oct, 2009 and since then is in continuous operation.

The authors are grateful to members of SCC beam development team for their constructive remarks & feedbacks which helped to define and integrate this system meeting user requirements. The authors gratefully acknowledge the sincere effort & active support rendered by the staff members of I&E Section of VECC in helping fabrication & successful commissioning of the system in time.

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