DRIVE SYSTEM INSTRUMENTATION FOR VEC SCC AXIAL-HOLE MAGNETIC FIELD MEASUREMENT

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Abstract

Characteristics of beam in the central region of the superconducting cyclotron are to a large extent influenced by the magnetic field it experiences during its passage through the axial-hole. Accurate knowledge of magnetic field in axial-hole is required in order to design the central region components and position the extraction elements. A probe drive with high resolution and repeatability was developed along with the required HMI to map the magnetic field through out this hole from median plane upto 3 meter above it. This paper describes the drive system, its control, data acquisition and instrumentation scheme.

DRIVE SYSTEM

The mechanical arrangement [1] for the measurement set -up can be divided into two parts: drive mechanism and probe holding mechanism. The drive mechanism has three lead screws and nuts. Lead screws of 1.5 m length are used to avoid complexity and to reduce fabrication problem and inaccuracy of the system. A stepper motor drives the lead screws. Rotational movement of the lead screws is restricted by two plates carrying hall probes, fixed at the top and the bottom ends of the lead screws. The stepper motor is fixed and the lead screws move up and down. Since the total required span of measurement is 3 m and the movement of the lead screws is restricted to 1.5 m, an extension of 1.5 m with bottom plate for mounting hall probes has been added. The plate at the end of the lead screw and extension form the probe holding mechanism. Two probes, one axial probe at the centre and one transverse probe at the outer radius, are fixed to each of the end plates. The end plates have provision to manually re-position the transverse probes at an angle of 90º. During one complete scan, the system can collect data over the complete required length of 3 m from the cyclotron median plane.

CONTROL AND DATA ACQUISITION

The axial-hole drive system can be broadly divided into two parts, the open-loop control of the drive system, and the magnetic field data acquisition system.

Control Scheme

The control scheme can be subdivided into following steps:

i. Optical limit switches are placed at both ends. At the start of each run, the drive is initialised by automatically moving it back till it touches the starting limit switch. As this operation is carried out

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in steps, an accuracy of 15 micron can be achieved.

ii. The system is then driven in steps upto 1500 mm. The heart of the control system is a stepper motor. It drives the three gear mounted lead screws which eventually move the hall probe assembly and position them correctly at 1.005 mm intervals. At this stage, the control software calculates the present absolute distance from the starting point and stores it in a file for ready reference. The control software confirms that the motor is powered (24VDC) before sending the drive pulses. In case of sudden power failure, the next drive signal is not sent and the last absolute position value is stored. When the mapping starts again after resumption of motor power, the software can easily recollect the last position value and starts scanning from that point.

iii. The motor stops after reaching the end point optical limit switch. The software scans the limit switch before each step. This results in end point detection at the theoretical accuracy of 15 micron. After reaching the end point, it shows mapping completion message on the human-machine interface (HMI) screen.

iv. After completion of a full length scan, the system automatically resets back to its initial position showing probe resetting message. It stops only if it reaches the starting point. Then it gives an option of another scan/ stop to the user.

Data Acquisition Scheme

The data acquisition scheme can be subdivided into following steps:

i. The data acquisition starts after the probe assembly stops at 1.005 mm interval. A delay of 5 seconds is given before each set of magnetic measurement to eliminate the chance of any kind of mechanical vibration.

ii. The control software communicates with the three channel FW Bell hall probe monitor through RS 232 serial port. Although four hall probes are installed in the assembly, the monitor can only read three of them at a time. Two successive scans give complete data for a fixed magnet current. The software initialises the serial port and sends command to measure the magnetic field for each channel. The hall sensors' data are collected from the read buffer of the monitor and channel-wise separated by the software. Ten sets of data are collected during the total measurement time of 5 seconds.

iii. The ten magnetic field data are statistically processed to minimise the chances of error. They are averaged and the dispersion value is checked. If the value of dispersion is 0 or more than 30 gauss the system rejects the whole set of data and takes a new set. If the dispersion is not met for second time, it gives a message of field monitor error.
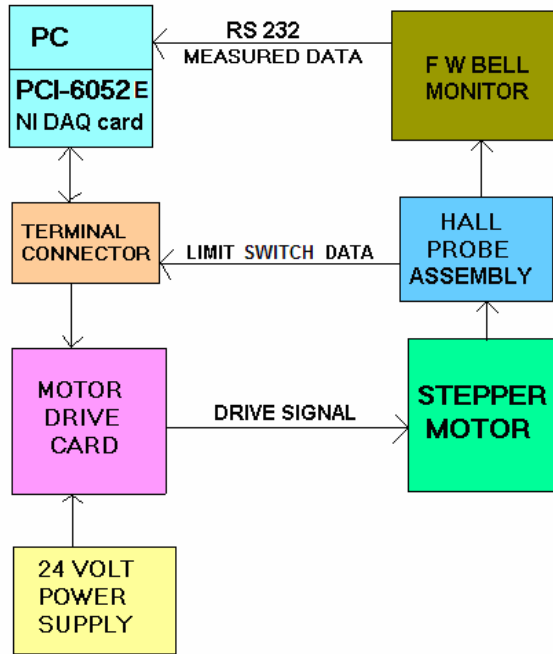

Figure 1: Basic Hardware Scheme of the System

INSTRUMENTATION SCHEME

Axial-hole drive system instrumentation can be described in two parts, its hardware and software.

Hardware

Figure 1 shows the basic hardware scheme. The system is controlled by a control software running on a dedicated computer (Fig. 2). The computer contains a PCI data acquisition card (NI PCI-6052E) for the digital I/Os and uses RS232 port for the magnetic field data acquisition. The DAQ card generates the digital pulse for the stepper motor and scans optical limit switches. External screw terminals board is used for easy access and connectivity of the various I/Os. This card takes the necessary 5V supply from the PCI slot itself. A separate control card for the motor is used to convert the pulse signal from PC (controlled by software) to necessary step signal for the motor. Software delay is incorporated in order to vary the time period of the pulse to adjust the speed of the motor. The Superior Electric make stepper motor (M111-FD-310) is a high torque (4.4 Nm) motor with 200 steps/rev. The motor runs at 24VDC and takes about 500mA current at its maximum speed (1000steps/sec). Holding current of 3A causes instantaneous stop and no further slippage. The motor has a very high resolution of 1.8° /step, thus

offering very high sensitivity. To calculate x, linear movement/step, where p is screw pitch and r is gear ratio

$$x = \frac{p \times r \times 1.8^{\circ}}{360^{\circ}} = \frac{5 \times 0.6 \times 1.8^{\circ}}{360^{\circ}} = 0.015mm$$

The system has a resolution of 15 micron. As a result, any length interval can be set with certainty. The stepper motor has an accuracy of ±5% of a step and this error is non cumulative from one step to the next which allows the system to be accurate within 2% over 1 mm interval. The system uses an optical limit switch for initial and end position detection and it searches for these two interlocks before each step (15 micron), causing highly accurate starting at each run. The system has very high repeatability, (Table 1) as it takes exactly same number of steps to reach same distances (even for full span travel). The FW Bell monitor (Fig. 2) with an accuracy of ±0.05% of reading, acquires the analog signals via co-axial cables from hall sensors and processes it to display locally (channel wise) as well as provide digital signals for serial communication. This monitor accepts command from the control software through serial port for measuring magnetic field values (3 channels) and sends those back to PC.

Table 1: Repeatability of the data produced.

Position (mm)	1st run (gauss)	2nd run (gauss)	Difference (gauss)
89.91	-22270.4	-22254.1	-16.3
94.905	-22171.1	-22163.5	-7.6
99.9	-22154.9	-22152.5	-2.4
104.895	-22195.8	-22198.1	2.3
109.89	-22266.1	-22268.5	2.4
114.885	-22335.5	-22336.8	1.3
119.88	-22380	-22377.5	-2.5

Software

The HMI is developed on Labview. The program has all steps to automate each scan starting from initialisation of the probe assembly to the end of the scan and re-positioning for the next scan. The program calculates the distance travelled with respect to the reference point determined by the initial limit switch and stores the last position after every step in a file for ready reference while restarting from the power loss situation. The program checks for the motor power each time before sending the drive signal to the motor and in case of any power cut or stuck motor, the software can't send any false signal to the motor. While restarting after resumption of power, it takes the last saved position value. After completing each full scan, it stops and automatically resets to its original starting position. The field data are collected with

minimum cable connections to reduce noise. The processed data is plotted instantaneously as the scan progresses for visual interpretation. The program starts acquiring data only after a pre-defined delay of 5 seconds to avoid any kind of vibrations or mechanical disturbance.
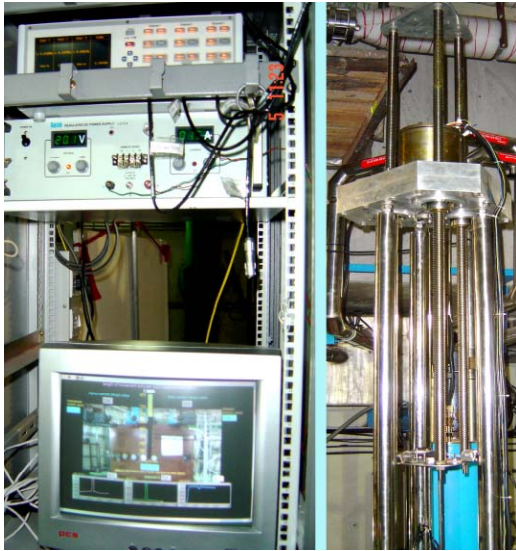

Figure 2: Basic Electronic and mechanical setup.

The HMI acquires multiple data for each specific position and discards any abnormal value, if collected, through a statistical process. It even can discard a whole set of data and take a new set, if required. Multiple rejections cause process to abort, showing error message. It also stores all the measured data in separate excel files for each scan with nomenclature containing date, time, current, probe positions etc. for user's convenience. All the operations are well informed to the user with consequent pop-up messages. In case of any error, the HMI shows first-up messages and can even abort whole measurement process, if required.
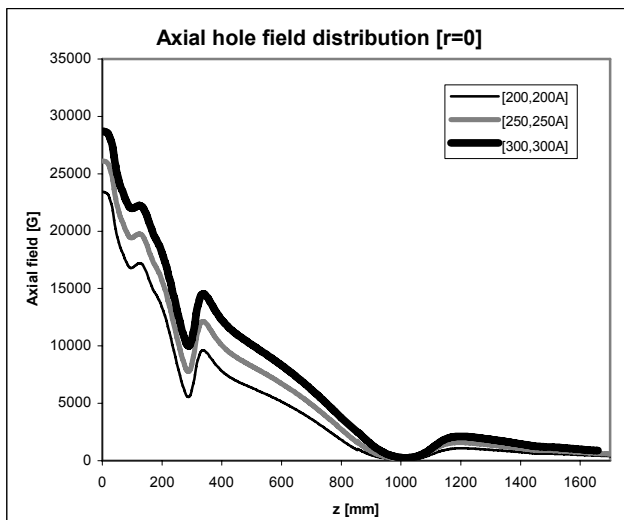

Figure 3: Axial-hole magnetic field distribution.

Conclusion

The well programmed HMI with open loop control, data acquisition system and the mechanical system was successfully used [2]. The performance of the drive was highly satisfactory and the axial-hole magnetic field mapping was completed within a few days. It produced useful data (Fig. 3) of axial-hole magnetic field measurement.

REFERENCES

[1] C. Nandi, S.K. Mishra, S. Gayen, R.N. Sharma, T.K. Bhattacharyya, G. Pal, C. Mallik and R.K. Bhandari, "Mechanical System for Magnetic Field Measurement through Central Axis and Inside Magnetic Channels for VEC K-500 Cyclotron", InPAC-2005, VECC, Kolkata, March 2005, p. 517.

[2] M.K. Dey, J. Debnath, U. Bhunia et al. "Magnetic Field Measurement and Correction of VECC Superconducting Cyclotron", InPAC-2006, Mumbai, November 2006, p. 285.