MEDIAN PLANE MAGNETIC FIELD MAPPING FOR SUPER CONDUCTING CYCLOTRON (SCC) IN VECC

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Abstract

The magnetic field at median plane of SCC Magnet (Peak field 5.8T) is measured over its operating range and upto 29 inch radius. The magnetic field is mapped at radial interval of 0.1 inch and angular interval of 1 degree. The complete map of 360 degree comprised of about 100K field points is obtained in less than 100 minutes. The field mapping system (MFM) is designed to minimise mapping time and human intervention. The control & data acquisition (DAQ) software (s/w) is developed to work as PC based TCP Client-Server mode to reduce the design complexity, system overload and debugging effort. The Server program is developed as windows console in 'C' and the Client is developed using LabView to provide a user friendly operation console along with online preliminary display and analysis of field data. This architecture provides a reliable and easily modifiable control s/w. The correctness of the magnet assembly is calculated from the acquired data, which in-turn represents the correctness of measurement system. A detailed study of the magnet characteristic is done. The first harmonics of the fields at different radii are obtained at all magnet excitation and corrected by coil-centering and shims placement. This paper also describes the major activities made during field mapping.

INTRODUCTION

The Magnetic Field Mapping (MFM) system comprises of a hardware system and a control & data acquisition software [1]. A search coil and Digital integrator combination are used to measure the difference in field between the center and any other point of the magnet [2]. The schematic diagram of the system is shown in Fig 1.

MFM DAQ HARDWARE

The hardware system consists of MFM jig, NMR Gauss meter, Digital integrator, DAQ Server PC and Client GUI PC. The MFM jig comprises of a centrally supported search-coil carrying arm, two Animatics smart motors, an angular encoder and a linear encoder. The schematic diagram of the jig is shown in Fig 2.

The radial movement range of the search coil is 29inch. An optical encoder system of 360 LPI was used to measure the search coil position. The angular position of the search coil carrying arm is measured by absolute rotary Inductosyn encoder (256/2 pole, 128/1 speed, 8.15 inch stator O.D.) associated with two dual channel preamplifier (219200) and AWICS converter board

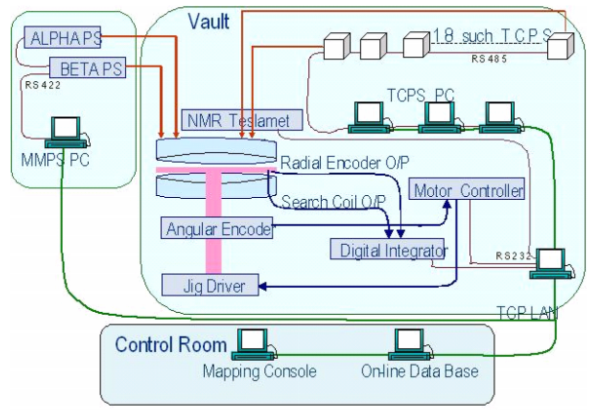

Fig 1: The schematic diagram of the system

(220500). A microcontroller based interface module was developed in house to read the angular position from the AWICS board online. The accuracy of the system was 1.7arc Sec.

The Measurement PC is placed at vault near the main magnet and connected by serial links with digital integrator, NMR Gauss meter, angular encoder and two smart motors. The Console PC is placed at the main control room. Both PCs are connected to the dedicated

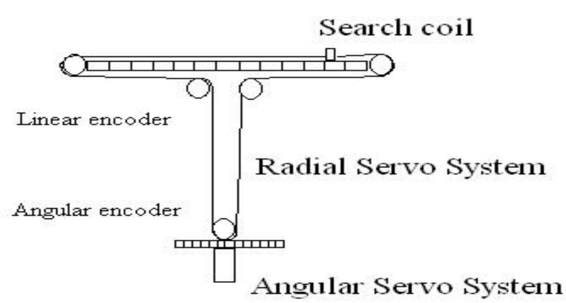

Fig 2: The schematic diagram of the jig

control LAN commissioned at Super-conducting cyclotron (SCC) building.

MFM DAQ SOFTWARE

The control & data acquisition software is designed in two independent modules i.e. Server Controller (SC) module and Client Graphical User Interface (GUI) module, to achieve distributed architecture, reduce system overhead, development and debugging effort. These two software modules incorporate the following features to satisfy the auto/manual mode of operation, minimum

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human interventions and minimum measurement time requirement of the system.

- Multi-threaded architecture
- Faithful communication, control and acquisition of data from the individual hardware modules, i.e. Digital integrator, NMR Gauss meter, Smart motors and Angular encoder.
- User-friendly graphical interface for full remote control and monitoring of the MFM system from the SCC main control room in Auto/Manual mode.
- Generation of warning/error messages for unacceptable events during mapping
- Acquisition, display and storage of other sub-systems data.
- On-line analysis of the acquired data.

DAQ Server Controller Software

The server s/w, designed to communicate with Client gui having a predefined IP address in Ethernet TCP/IP protocol to prevent unauthorized access, developed in C using Windows API performs following three tasks simultaneously.

- Receive command from Client GUI and decode the command to invoke appropriate job.
- Execute one of the jobs. i.e. initialization of the system, radial data acquisition, setting azimuthal position and reading NMR gauss meter.
- Execute a watchdog timer independently to monitor any unacceptable event and notify Client GUI.

DAQ Client GUI Software

The Client GUI module developed in LabVIEW 6.1, enables users to control the complete process of field mapping comprises of acquiring, storing and on/off-line analysis of the data. This software performs following three tasks simultaneously [3].

- Communication with SC s/w for automatic and manual mode of operation, control and monitoring the MFM procedure and field data acquisition and storing.
- Transaction with a centralized Oracle Database server to read and display different subsystem parameters to ensure the magnetic field during the mapping.
- Online 2D visualization of the acquired field data for comparing the actual and theoretical profile the magnetic field.
- Offline Fourier analysis of MFM data stored in database for the analysis of azimuthal field modulation.

DAQ ACTIVITIES

The Magnetic field mapping of SCC magnet comprises of the following activities.

- The starting point of the search coil over radial movement is fixed at -1.28 inch beyond centre for reproducibility check of the measured data. This requires precise positioning of the optical scale of the encoder with respect to optical limit switches placed on the radial arm.
- The tuning of fine and coarse preamplifier of the angular encoder is repeated to reduce measurement error introduced by fringe field effect during the higher values of coil excitation. The tuning requirement was reduced for different coil excitation after providing proper magnetic shielding on encoder signal processing electronic modules. To maximize the accuracy, repetitive adjustment of phase and frequency of angular encoder system was done after installation of the jig inside SCC magnet and placement of associated electronics at vault.
- The digital integrator was adjusted repeatedly for various field magnitudes to optimize the gain and offset error value.
- The search coil (height 0.72 inch and o.d. 1 inch, 20,000 turns of 40 SWG wire [1]) and digital integrator assembly was calibrated by moving the search coil from centre and RF centre and measuring difference of the magnetic field by NMR gauss meter between these two points. The calibration factor was 0.4766 mGauss/ 10-8 volt-sec of digital integrator.

RESULT

Extensive magnetic field mapping has been carried out at different main coil excitations. The median plane magnetic field distribution is three-fold symmetry dominated due to three-sector geometry of the cyclotron. Deviation from perfectly three-fold symmetry arises out of manufacturing tolerances and assembly errors. The goal was to reduce the error harmonics to manageable proportions at the important places by adding iron shims, especially the 1st harmonics at the extraction region. The data analysis comprises of the following major activities: (i) processing of the measured raw data, (ii) reproducibility check up, (iii) finding the magnetic symmetry axis by minimization of second harmonic component, (iv) correction of average iron field distribution by adding iron shims and (v) minimization of first harmonic component by shimming of iron, which are completed successfully.

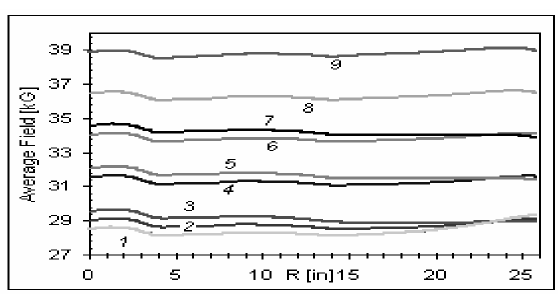

Fig 3: Average field for following main coil excitations (I_{alpha}, I_{beta}). 1: (475, 175), 2: (425, 225), 3: (375, 275), 4: (453, 290), 5: (403, 340), 6: (481, 356), 7: (509, 422), 8: (459, 472), 9: (537, 487)

The radial distribution of B_{av} for different current settings (I_α, I_β) is shown in Fig 3. Iron shims were added to remove unwanted dips in the average iron field at about 4", 7" and 14" radii (Fig 4). The distributions of 1^{st} harmonic field at different stages of corrections are shown in Fig 5 by map1, map2 and map3. Finally, the 1^{st} harmonic field is within 7 gauss near the extraction radius.

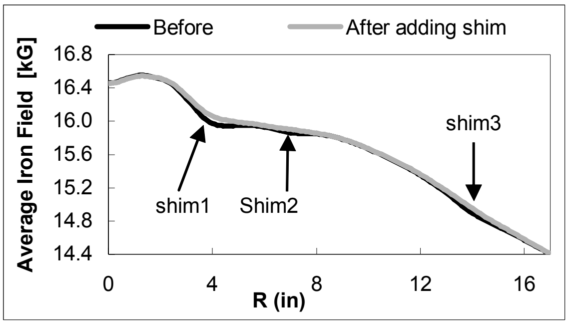

Fig 4: B_{av} correction by adding shim 1,2 and 3

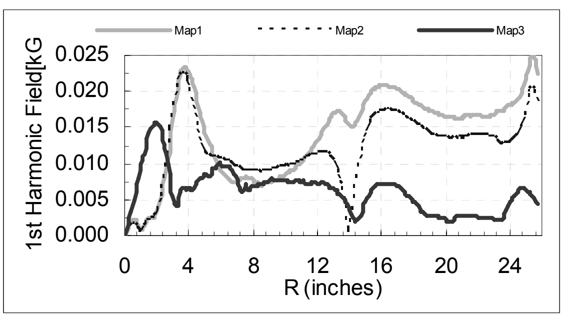

Fig 5: Minimization of 1^{st} harmonic field profile

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CONCLUSION

The MFM system is installed and complete field mapping at different coil excitation are performed successfully. The maximum radial and azimuthal field variations of SCC magnet are 4 KGauss/inch and 1 KGauss/deg respectively at maximum excitation. The objective i.e. to measure the field with the accuracy of 100 ppm i.e. 1 in 10^4 Gauss is achieved successfully using search coil of optimised dimension, digital integrator of 10^{-8} volt-sec resolution, 17 bit angular encoder with 1.7 arc-sec accuracy and linear encoder of 70 µm resolution with 10 µm accuracy. The analysis is done on measured field data and the subsequent corrections are incorporated on the magnet to improve the field quality by reducing the 1^{st} harmonic content.

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