Development of Long Coil Dynamic Magnetic Field Measurement System for Dipole Magnets of HEPS Booster

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Abstract

A magnetic field measurement system for dipole magnets of High Energy Photon Source Booster is designed and developed. The system uses the long coil upflow method to measure the dynamic integral field of the magnet, and the long coil transverse-translation method to measure the integral field distribution error of the magnet.

In this paper, the design and implementation of the magnetic measuring system are introduced in detail, and the magnetic field measurement results of the prototype magnet are shown. The measurement results show that the repeatability of the dynamic integral field measurement system is about 2 in 10,000, and the repeatability of the uniform distribution of the integral field is better than 1 in 10,000, which meets the test requirements of the discrete integral field of bulk magnets ±1‰ and the uniformity of the integral field $\pm 5\times 10^{-4}$@6GeV and $\pm 1\times 10^{-3}$ @0.5GeV.

Introduction

Dipole magnet of HEPS Booster is 1Hz AC magnet with DC bias. The magnetic field varies from 0.05T to 0.68T, and the rise time is 400ms, the flat top time is 200ms, and the fall time is 200ms.The magnet is H-shaped linear structure, with an air gap height of 34mm, an effective length of 1450mm, and an external size of about 1500mm.

The field is designed to reach 40×20mm, and the field uniformity of high and low fields is required to be 1×10^{-3} and 5×10^{-4}, respectively. The integral field dispersion of magnet is required to be 0.1%.

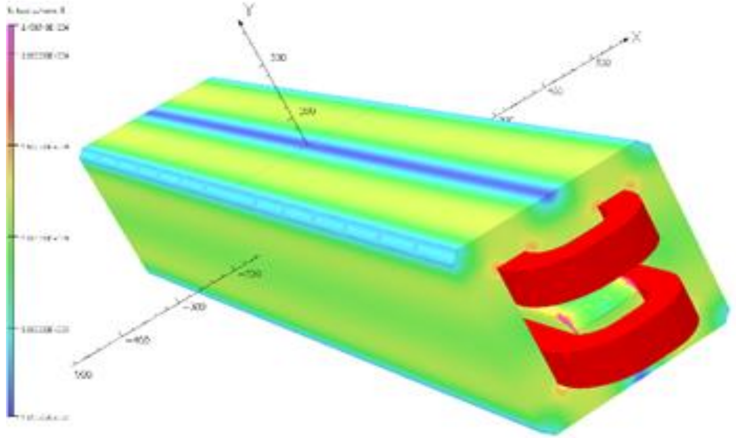
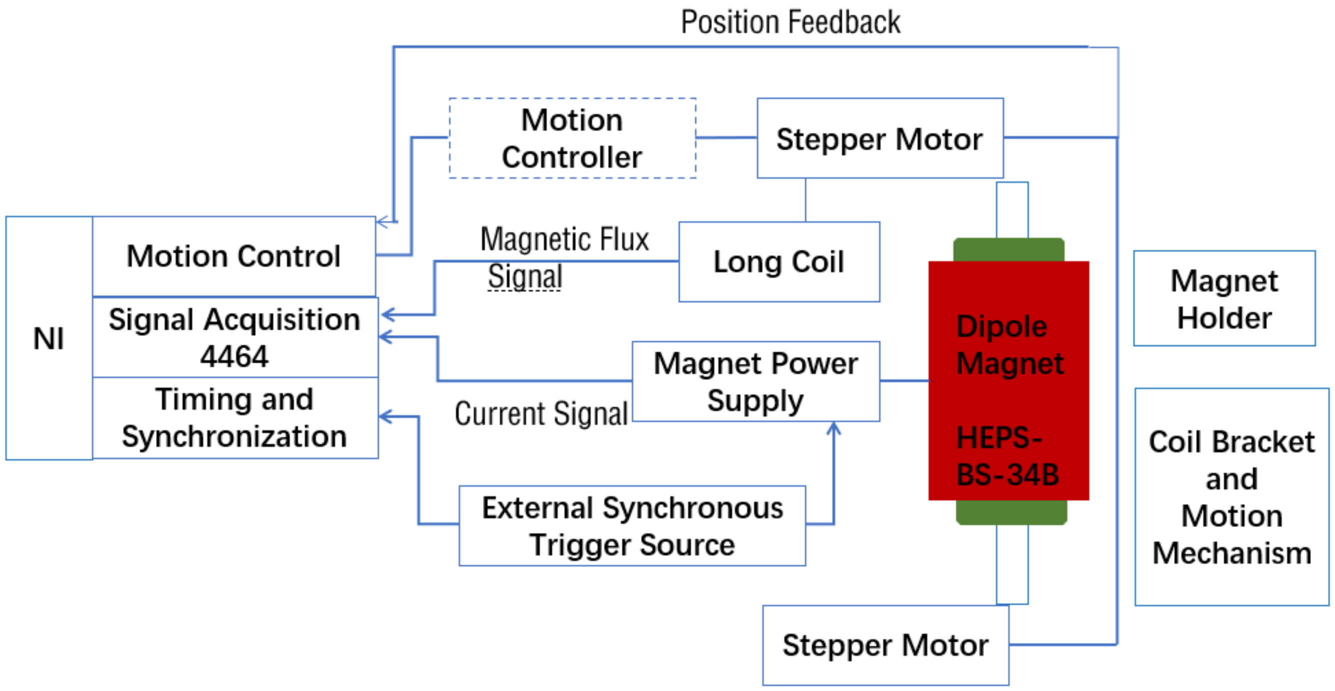


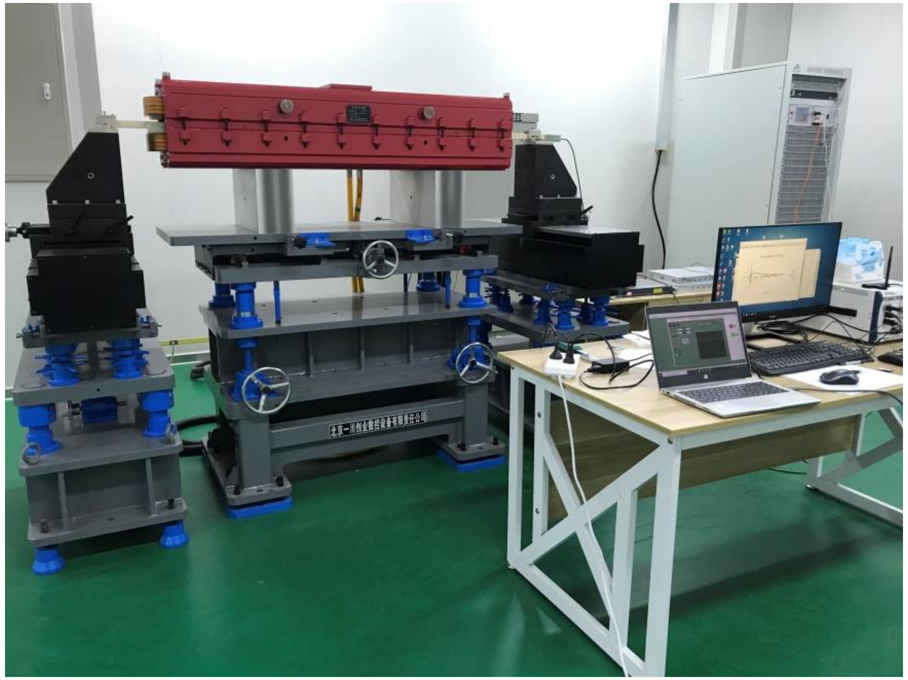
Fig. 1 Physical Design Model of Dipole Magnet for HEPS Booster（HEPS-BS-34B）

Table 1 Design Parameters of Dipole Magnet

Number	128	Magnet Gap（mm）	34
Magnetic Effective Length（m）	1.45	Core Length（m）	1.425
Chord and Arc Difference（mm）	8.9	Width of Pole Surface（mm）	105
Maximum Working Magnetic Field（@6GeV）（T）	0.68	Good Field Range（mm）	30×20
Minimum Working Magnetic Field（@500MeV）（T）	0.05	Integral Field Uniformity in Good Field Area（@0.5GeV/6GeV)	$1\times10^{-3}/5\times10^{-4}$
Turning Radius（m）	29.54	Discreteness of Integral Magnetic Field between Magnets	0.1%

Frame Diagram and System Composition of Magnetic Measuring System for HEPS BS Dipole Magnet





The magnetic measuring system consists of a over 2.0m long measuring coil, a mechanical platform with a stroke within plus or minus 300mm, a motion control system and a signal acquisition equipment.

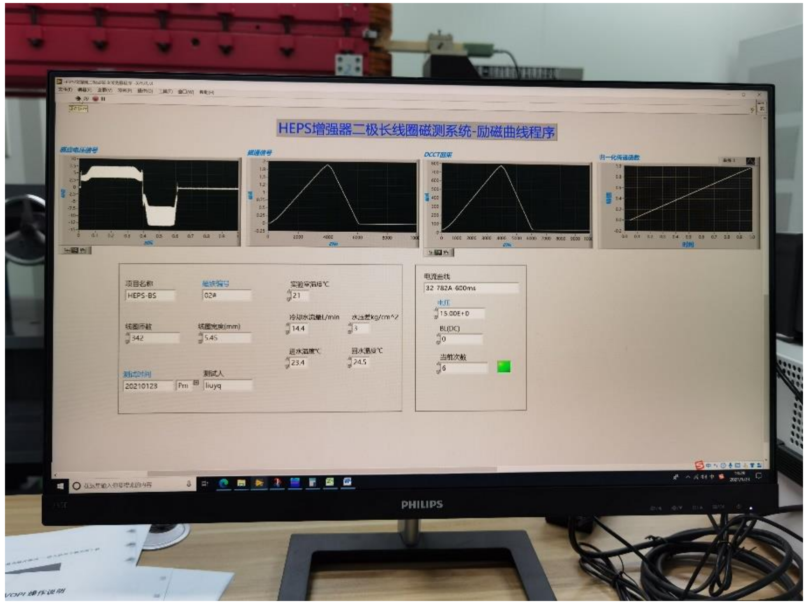
Hardware and Software Implementation of Magnetic Measuring System-1

The magnetic measuring system selects Yasawa stepper motor and Taidao iMac-FX controller, and the signal acquisition equipment adopts 24-bit NI-4464 signal acquisition card.

Through the EQU position comparison function of the controller, the motion speed, uniform motion interval and the starting and stopping position of data collection are programmed to control.

The long coil winding frame width is 4mm, the length is 1.8m, and the number of turns is 342.The coil uniform motion range is greater than 40mm, the positioning accuracy is ±3μm, and the repeated positioning accuracy is ±1.5μm.

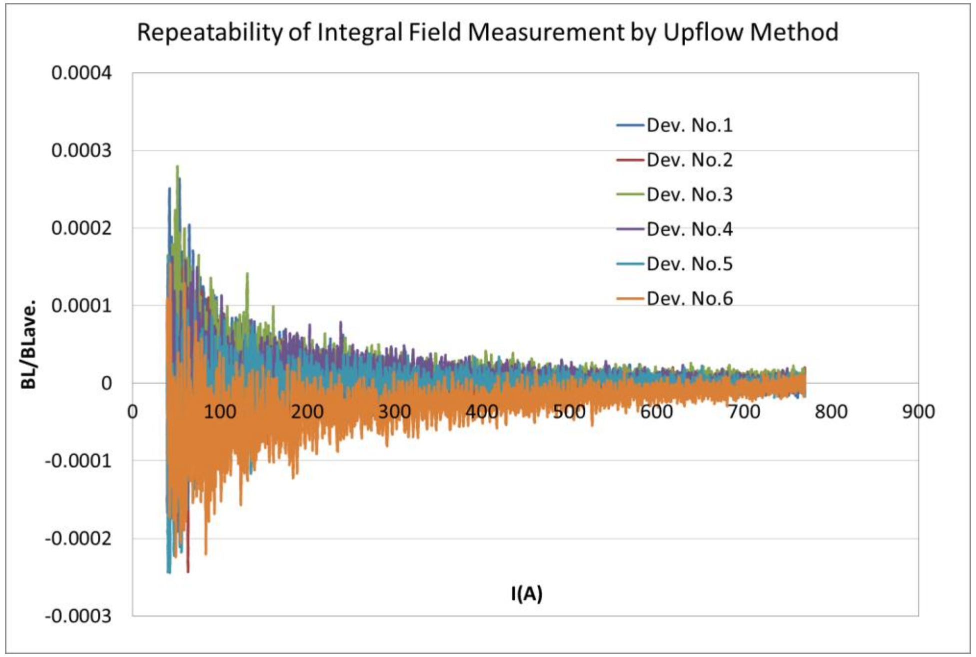
Hardware and Software Implementation of Magnetic Measuring System-2



The integral field, excitation curve and current magnetic field waveform were measured by the long coil upflow method, the field uniformity was measured by the long coil translation method under DC current, and the coil coefficient was calibrated by the integral field measured by the Hall point measurement system.

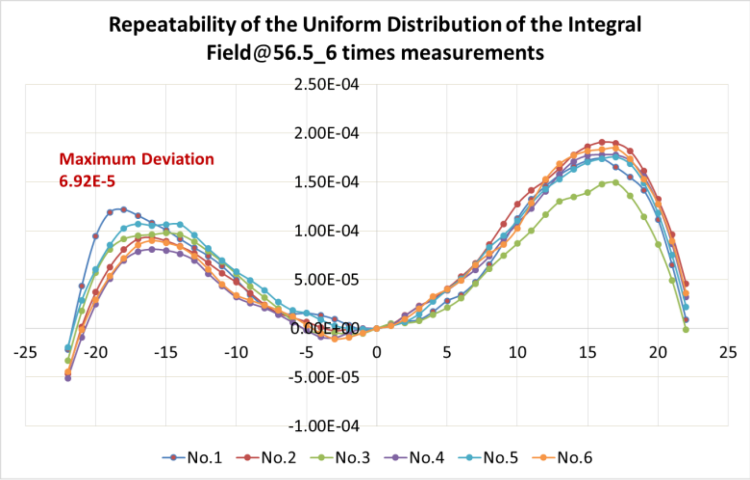
The magnetic measurement program is specially written by LabVIEW, which is divided into the translation long coil uniformity measurement program and the long coil upflow method integral field measurement program.

The Reliability of the Long Coil Dynamic Magnetic **Measuring System**



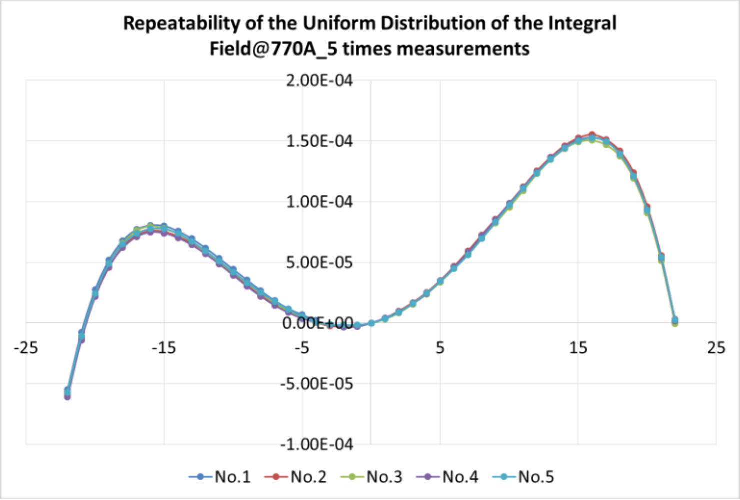
Repeatability of Integral Field Measurement by Upflow Method

（Deviation of each measurement BL relative to the mean of 6 times measurement）



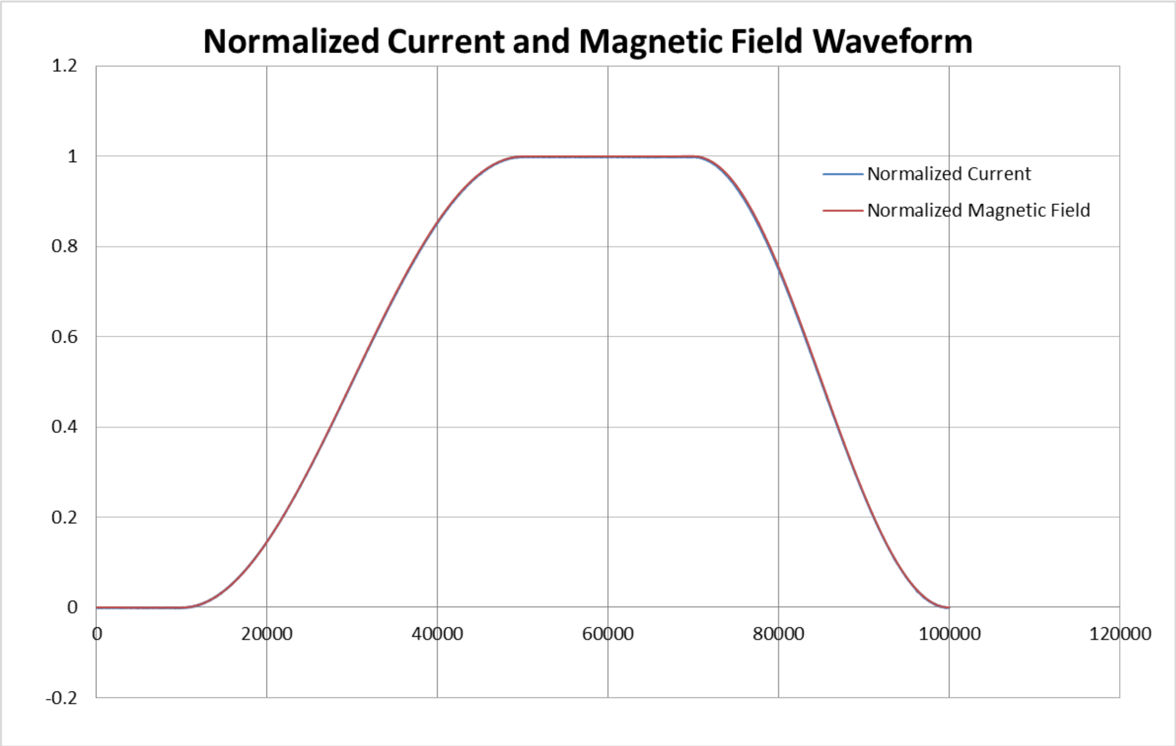
Repeatability of Field Distribution Error Measurement @56.5A&@770A

The repeatability of the field distribution error with the translation method is better than the 7×10^{-5} repeatability of the 5 times measurement.

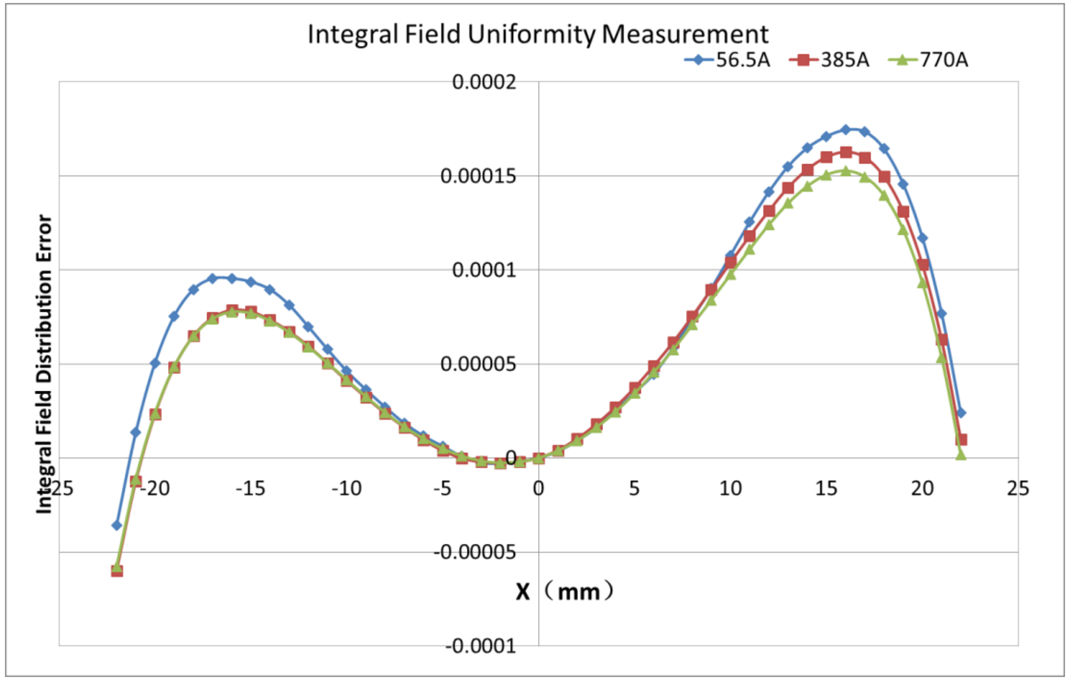


The repeatability accuracy of integral field measurement by upflow method is better than 3×10^{-4} at low field, 1×10^{-4} at midfield and 3×10^{-5} at high field.

Part of the Results of the Prototype Magnet



Normalized current and magnetic field waveform



Field uniformity measurement @56.5A,@385A,@770A

@56.5A， -3.6×10^{-5} ~ 1.75×10^{-4}

@385A， -6.0×10^{-5} ~ 1.63×10^{-5}

@770A， -5.77×10^{-5} ~ 1.53×10^{-4}

(The measuring range of the field distribution is ±22mm)

Summary

1. The design parameters and measurement requirements of the BS Dipole magnet of HEPS are introduced.
2. The framework, system composition, hardware and software implementation, measurement method and reliability of the magnetic measuring system are also introduced.
3. The repeatability of integral field measurement and field distribution error measurement both meet the measurement requirements.
4. Some magnetic test results of the prototype magnet are shown, and the central magnetic field, effective length and field uniformity of the prototype meet the design requirements.