TUAP051
hep-ex/0111025

THE NEW MAGNETIC MEASUREMENT SYSTEM AT THE ADVANCED PHOTON SOURCE *

Yu.Eidelman, B.Deriy, O.Makarov, I.Vasserman, APS, Argonne, IL 60439, USA

Abstract

A new system for precise measurements of the field integrals and multipole components of the APS magnetic insertion devices is described. A stretched coil is used to measure magnetic field characteristics. The hardware includes a number of servomotors to move (translate or rotate) the coil and a fast data acquisition board to measure the coil signal. A PC under Linux is used as a control workstation. The user interface is written as a Tcl/tk script; the hardware is accessed from the script through a shared C-library. A description of the hardware system and the control program is given.

1 INTRODUCTION

A new system for precise measurements of magnetic field integrals and multipole components of different types of insertion devices (IDs) is created as an upgrade of the Magnetic Measurement Facility at the APS [1]. The main reasons for upgrading the existing system were:

- To increase accuracy and reproducibility of acquired data. Long cables between motor drives and stepper motors in the existing system produce an excessive noise interfering with the measured signal. Integrators in the existing system take 4 data values per coil turn. The new system uses ≈ 1000 data points of coil signal for analysis, leading to better accuracy. Different error sources presented in the coil signal can be analyzed, particularly coil vibrations.
- To simplify the system and increase reliability for ease of maintenance, future developments, and possible duplication of the system in other projects. In the existing system VME, Euro, as well as non-standard crates, have been used. It has been very hard to maintain and almost impossible to reproduce the system.
- To allow integration of the results of the magnetic measurements with other APS databases and utilities. The Linux OS instead of Windows has to be used in order to reuse software modules developed by Operations Analysis Group [2] for the APS storage ring.
- To provide more convenient data analysis in both stand-alone and network operation.
- To add more features, such as a translation mode, for measuring multipole magnetic field components.

2 PRINCIPLE OF THE MEASUREMENTS

The stretched coil is used to measure magnetic field integrals. The coil signal is proportional to the time derivative of the magnetic flux through the coil cross-section. The measurements are performed at constant coil rotation (translation) speed. There are four different options for measurements.

Integrals and **rotation** modes. Signals are measured for full turns of the coil. Two turns, clockwise (CW) and counter-clockwise (CCW), are performed to exclude systematic errors. The measured data are applied to calculate absolute values of the first or the second (if the coil is twisted by 180° [3]) magnetic field integrals. A set of approximately ten points across the gap of the ID is measured to calculate multipole magnetic moments.

Translation mode. The linear motion of the coil to measure the magnetic flux changing in the horizontal or vertical direction is examined, allowing significant reduction in the measurement time of the multipole moments.

Variable field mode. The coil does not move. This mode is designed for measurements of IDs with switching electromagnets [4].

3 HARDWARE DESCRIPTION

A block diagram of the new system is shown in Fig. 1. Eight smart motors from Animatics Corp. [5] are used. Each servomotor has an encoder, a motor drive, and a motor controller—all integrated in one unit, thus reducing the level of the electrical noise, compared to the existing system. These smart motors have two standard serial ports—RS-232 and RS-485. All motors connected in parallel to the RS-485 communication line are controlled by the Pentium III computer under Linux OS through a RS-232/RS-485 converter.

The stretched coil conventional configuration with parallel wires is being used for measurements of the first field integrals and multipole components. The measured signal is amplified by a SCXI-1120 National Instruments amplifier. The gain is set to 2000, and the bandwidth is set to 10 kHz. A 500 kHz data acquisition board PD2-MFS-500/16 from United Electronics Industries [6] is used to measure the am-

* Supported by the U.S. Dept. of Energy, BES, Office of Science, under Contract No. W-31-109-Eng-38.

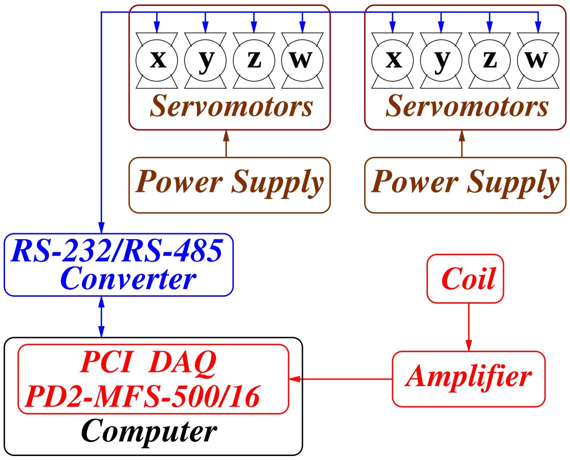

Figure 1: Layout of the upgraded system.

plified signal. The Linux driver for this PCI DAQ board was provided by the manufacturer.

4 SOFTWARE DESCRIPTION

A new Multipoles & Integrals—Software System (MISS) has been written. It consists of two parts: a Tcl/tk script and a shared C-library.

4.1 Tcl/tk script

The Tcl/tk script describes a user interface and data processing and uses a shared C-library for hardware access. The script language includes all embedded instruments to create the user-friendly interface and to use a shared C-library. Besides, MISS uses utilities developed by the APS Computer Support Group for this language. MISS operates under Linux and provides the user interface through a set of windows and worksheets (see Fig. 2).

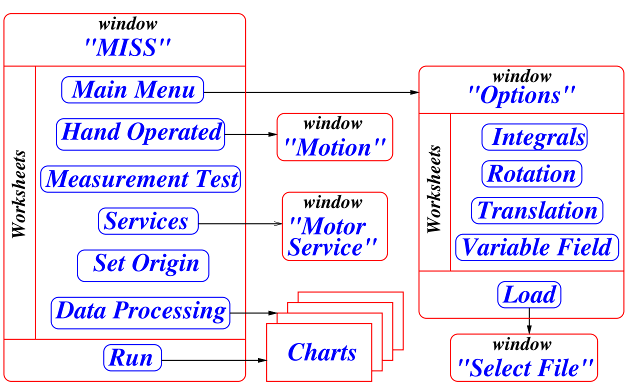

Figure 2: Software chartflow diagram.

Figures 3 and 4 demonstrate examples of the user interface.

4.2 Shared C-library

The hardware is accessed from the script through a shared C-library. This library consists of two command sets—one

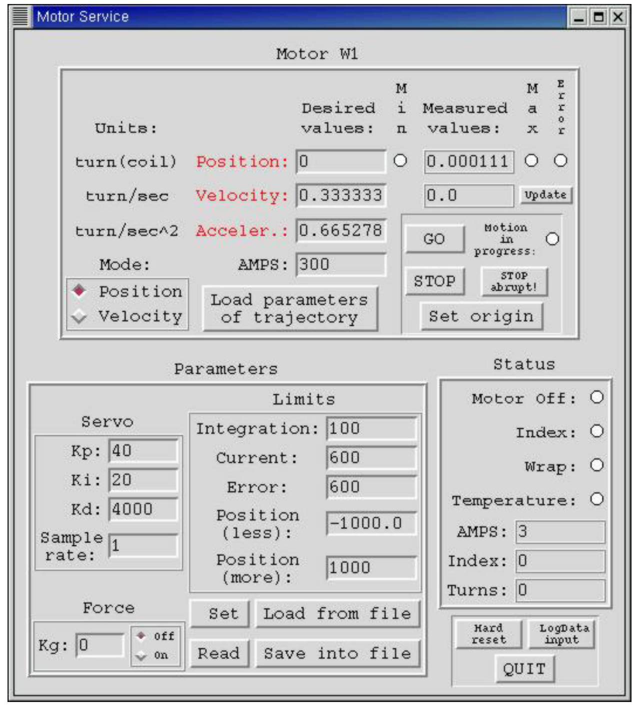

Figure 3: Window "Motor Service."

for smart motors and another for the DAQ board. The serial port driver "ttyS" with appropriate setting of the structure "termios" is used to control the motors. The Linux driver "pwrdaq" is used to control the DAQ board. Some of the DAQ board commands are based on the corresponding C-functions of this driver. The complex procedures providing synchronization between coil motion and data acquisition are included in the C-library. These procedures combine calls to the motors and the DAQ board in the required sequence. So, the execution of such commands cannot be interrupted by a Tcl/tk script command.

5 SYNCHRONIZATION OF THE COIL MOTION AND DATA ACQUISITION

This process includes two steps.

Integrals and **rotation** modes. At the first step, the choice of coil "trajectory" (velocity and acceleration of the rotation) determines the calculated delay between initiating the coil motion and starting the data acquisition. The second step includes matching the additional delay to achieve agreement between the signals measured for CW and CCW coil turns. This matching is based on the assumption that plots of measured signals (voltage versus the coil's turn angle α) for both of these rotations must be mirror symmetric, if delays are chosen correctly. Figure 5 shows the measured signals for both cases after integration and subtraction of offsets. It was found that the additional delay is equal to 25 ms for a calculated delay of 550 ms.

Translation mode. The first step is identical to the first step in the rotation mode. The additional delay was determined

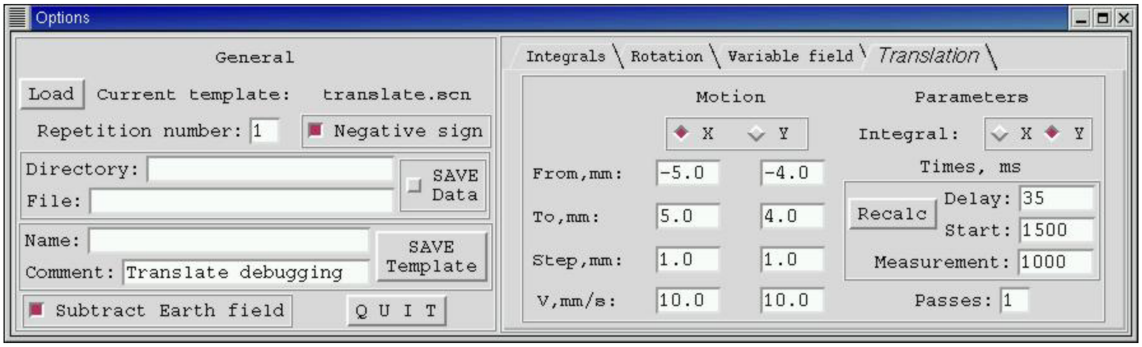

Figure 4: Worksheet "Translation" of the window "Options".

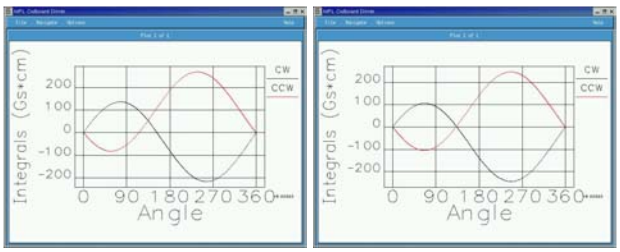

Figure 5: Integrals of measured signals for calculated (left) and matched (right) starts of the data acquisition.

by using the rotation mode with the same velocity and acceleration of the smart motors. This delay is equal to 35 ms for a calculated delay of 1500 ms.

6 DATA PROCESSING AND SOME RESULTS

Different algorithms are used to obtain the magnetic properties of the IDs.

A) Measuring of the first and second integrals includes the following steps:

1. Fitting of the functions $A_i \sin(\alpha + \phi_i)$ on noisy coil signals for CW ($i = 1$) and CCW coil ($i = 2$) turns.

2. Calculating of magnetic field integrals I_x, I_y for each coil turn from fitting parameters A_i, ϕ_i.

3. Repetition of previous steps to improve accuracy and define rms errors of measurements.

The statistical error of integrals I_x, I_y (measured for the Earth's magnetic field) is equal to $\pm$ 0.4 Gs·cm (improved from $\pm$ 2 Gs·cm before upgrading).

B) Measuring of the integrated multipole moments in the rotation mode includes all steps from case A) for a set of points r_i across the ID gap and, after that:

4. Fitting of the polynomials $\sum_{k=0}^{n} b_k r^k$ of the power n on the sets $I(r)$ (separately for arrays I_x and I_y).

Coefficients b_k are integrated multipole moments.

C) Measuring of the integrated multipole moments in the translation mode includes:

1. Fitting of the polynomials $\sum_{k=0}^{n} b_k r^k$ of the power n on noisy signals for a few coil passes across the gap of the ID.

2. Averaging of obtained coefficients b_k over the set of coil passes to reduce the statistical errors.

Note that the translation mode saves significant time in measuring the integrated multipole moments in comparison with the rotation mode. Measurements have to be done for both horizontal and vertical coil orientations.

A strong short magnet was used to evaluate the accuracy of the measurements of the multipole moments. Table 1 shows these results which were obtained for the translation mode.

Table 1: Multipole moments measurements.

k	b_k	δb_k	Units
0	652.8	$\pm$0.1	Gs·cm
1	2208	$\pm$2	Gs
2	1840	$\pm$7	Gs·cm^{-1}
3	-1167	$\pm$48	Gs·cm^{-2}
4	-2929	$\pm$127	Gs·cm^{-3}
5	1985	$\pm$203	Gs·cm^{-4}
6	460	$\pm$518	Gs·cm^{-5}

A few programs from the SDDS Toolkit [7] are used for polynomial fitting, data management, and displaying charts.

7 REFERENCES

[1] L. Burkel et al., "The Insertion Device Magnetic Measurement Facility: Prototype and Operational Procedures," Argonne National Laboratory Report No. ANL/APS/TB-12, March 1993.

[2] http://www.aps.anl.gov/asd/oag

[3] D. Frachon et al., "Magnetic Measurements of the Elliptical Multipole Wiggler Prototype," Argonne National Laboratory Report No. ANL/APS/TB-22, March 1995.

[4] E. Gluskin et al., "An Electromagnetic Helical Undulator for Polarized X-rays," AIP Conf. Proc.: Synchrotron Radiation Instrumentation, vol. 521, P. Pianetta, J. Arthur, and S. Brennan, eds., AIP (2000) pp. 344–347.

[5] http://www.smartmotor.com.

[6] http://www.PowerDAQ.com.

[7] http://www.aps.anl.gov/asd/oag/manuals/SDDStoolkit/SDDStoolkit.html