ISBN: 978-3-95450-207-3 doi:10.18429/JACoW-MEDSI2018-WEPH06

UPGRADE OF MAGNETIC MEASUREMENTS LABORATORY AT ALBA SYNCHROTRON

J. Campmany†, J. Marcos, V. Massana, L. Ribó, F. Becheri, R.A. Petrocelli
ALBA-CELLS, 08290 Barcelona, Catalonia, Spain.

Abstract

Along 2017 and 2018, a complete upgrade of hardware and software at ALBA magnetic measurements lab has been done. Regarding hardware, a relevant innovation has been the replacement of DC motors by step motors in new Hall probe, flipping and rotating coil benches. Up to now, these kind of continuous measurements usually were done with DC motors because steppers were considered unable to fulfil the required movement smoothness. However, recent innovations in drives made feasible its use. In our case, we tested the performance of upgraded benches and they reach the same accuracy than the former DC versions. In all upgraded systems, we used the ALBA standard IcePAP motor driver [1], taking advantage of firmware upgrades, including the possibility of triggering data acquisition by signals generated from different axes selectable via software. Regarding software, control systems have been unified to Tango package.

HALL PROBE BENCH

The Hall probe bench at ALBA, used to map the magnetic field over 3D regions, was originally built on 1997 by Ramem Company as shown in Fig. 1. It was fully characterized when it was initially commissioned [2], and over the years the system had undergone several hardware and software upgrades in order to improve its performance. In particular, in 2005-2006 the control system was completely revised in order to migrate it from EPICS to TANGO and to implement the on-the-fly measurement mode, which allows acquiring data while the system is moving [3].

However, one of the critical hardware components, the motion driving system, a Delta Tau VME PMAC, had never been replaced and by the end of 2016 it has become obsolete. Therefore it was decided to replace it by a state-of-the-art motion controller providing equivalent or even better capabilities. The selected system was a Delta Tau Power Brick AC unit, which integrates a Power PMAC controller. In parallel, it was also decided to develop a new version of the control system, having it up-to-date with ALBA standards, in order to take profit of the tools that have been developed last years. The objective has been to control ID laboratory benches with the same architecture and code versions used in the controls of both Beamlines and Accelerator at ALBA.

The hardware replacement took place in Oct-Dec of 2016. Afterwards, between Dec 2016 and Feb 2017 the hardware was tuned and adjusted. Finally, in the period Feb-Apr 2017 the new control system was successfully commissioned and debugged. Its performance is the same as the old one.

Figure 1: Old Hall probe bench based in DC motors upgraded in 2016.

In parallel, we have built a new Hall probe bench entirely based on step motors and with a control system similar to the upgraded old bench. The new bench, presented and characterized as published elsewhere [4] can be seen in Fig. 2. Software and hardware improvements are sketched in Fig. 3.

Figure 2: New Hall probe bench based in step motors.

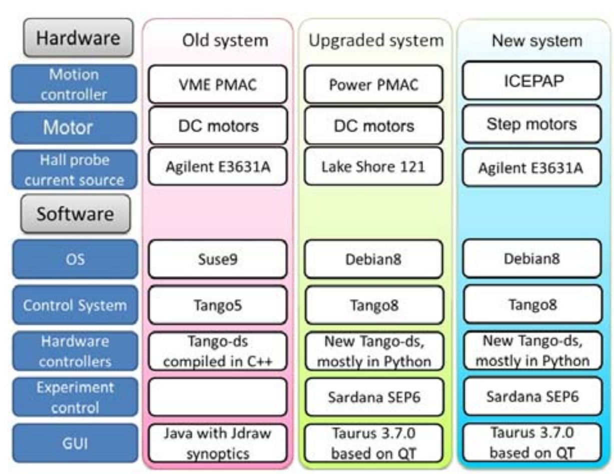

Figure 3: Hardware and Software upgrades of the Hall probe benches at ALBA.

† campmany@cells.es

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According to tests published elsewhere [5], the system repeatability when measuring small-gradient magnetic fields is ~10 µT, In the case of measuring small period oscillating fields as those typical of in-vacuum undulators, the repeatability worsens by up to ~60 µT. Also, using the usual procedure of identifying poles as those points where $\partial By/\partial z = 0$, the rms error of the pole positions is of the order of 1 µm, and the rms error of the associated peak field strength is 40 µT. Thus, it is worth noting that the rms optical phase error calculated from the measured field is reproducible within 0.01°.

This performance is even slightly better than that of the upgraded old bench moved with DC motors. As a summary, in Table 1 we compare the accuracies reached with the old Hall probe bench operated with DC motors with the accuracies reached with the new system.

Table 1: Hall Probe Benches. DC Versus Step Motors

	Old bench DC motors	**New bench Step motors**
Error homogeneous field	±10 µT	±10 µT
Variable field error	±60 µT	±60 µT
Position error	±30 µm	±20 µm
Position repeatability	±1 µm	±1 µm
Phase error accuracy	±0.02°	±0.01°
Measurement velocity	15 mm/s	13 mm/s

FLIPPING COIL BENCH

The flipping coil bench at ALBA, designed to determine low-value field integrals from small gap devices, was purchased as a turn-key system from ESRF on 2006. The system made use of linear and rotating stages based on DC motors, controlled by a 6-axis Newport MM4006 motion controller. The control system consisted of macros running on Igor Pro software.

The copper multiturn-wire coil is arranged along the z-axis (longitudinal) and stretched between both stages (only the slave stage can be manually moved), and connected to a Digital Voltmeter (DVM). The x- and y-stages are used to position the coil for measurement and to scan the variation of field integrals. The rotational r-stage is used to rotate the coil around the z-axis and to determine the local value of the field integral. The system is shown in Fig. 4. In our case, the coil has the following dimensions: 4.1 m long, 4 mm width (nominal value) and has 15 turns. Repeatability errors have been studied and the reproducibility of first field integral measurements is $< 10^{-5}$ T·m [6].

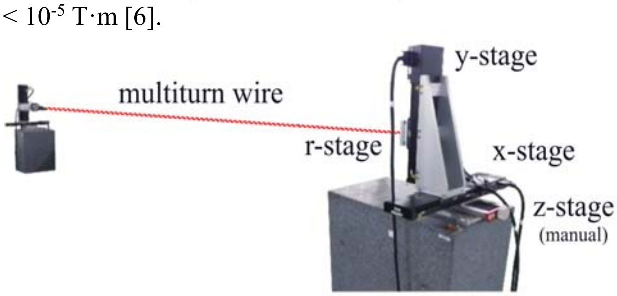

Figure 4: Flipping coil system at CELLS, with two motion stages on granite blocks.

In 2016 the motion controller unit broke down, and given that the system was not commercially available anymore and that no technical support existed, it was neither possible to replace nor to repair it. Therefore it was decided to replace the motion controller by the standard solution used at ALBA, an IcePAP unit. However, current version of IcePAP firmware only implements stepper motor control. As a consequence, it was necessary to send the linear/rotating stages to the manufacturer (Newport) in order to have their DC motors replaced by stepper ones.

The hardware refurbishment was complemented with the development of a new control system based on Tango conforming ALBA standards, as sketched in Fig. 5.

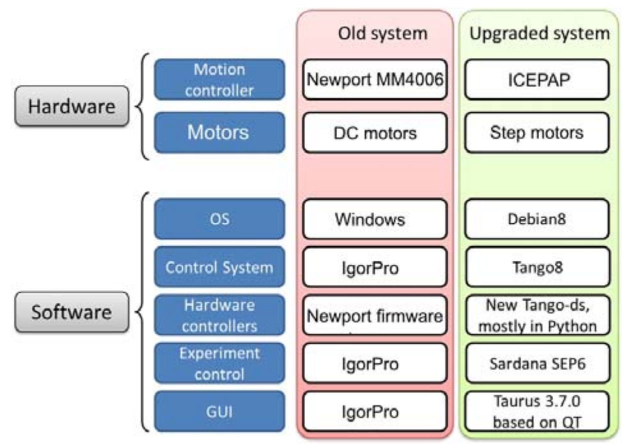

Figure 5: Hardware and Software upgrades of the Flipping Coil bench at ALBA.

This new control system, in addition to allowing for an easier maintenance, will make it possible to combine in a straight forward way the operation of the Hall probe and the flipping coil benches, which is a particularly convenient feature in the case of measuring Insertion Devices.

The hardware upgrade was carried out on Feb-Apr of 2017; the system was reassembled on May 2017 and the control system was developed and commissioned on Jun-Jul 2017. The new system displays a performance similar to the original one, with a *rms* repeatability of field integrals of 10^{-6} T·m. Results are summarized in Table 2.

Table 2: Repeatability of Flipping Coil Bench

	DC motors	**Step motors**
Background	$1\cdot10^{-6}$ T·m	$1\cdot10^{-6}$ T·m
With field (relative)	$7\cdot10^{-3}$ T·m	$1\cdot10^{-3}$ T·m

ROTATING COIL BENCH

The rotating coil bench at ALBA, used to determine the integrated field harmonics of accelerator magnets with lengths up to 0.5m, is a second-hand system purchased from CERN on 2008. It is shown in Fig. 6. The system rotation is driven by a DC motor controlled by a Maxon PCU2000 unit. The coil signal is acquired by means of VME integrators based on voltage-to-frequency

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converters developed at CERN, and the control system is based on LabVIEW running on a Sun Ultra workstation.

The repeatability of such a system in the determination of the main harmonic is better than $1 \cdot 10^{-4}$, and the repeatability in the determination of the normalized high order harmonics up to the 15th is of the order of $1 \cdot 10^{-5}$ [7].

Figure 6: Old rotating coil bench.

System hardware and software were obsolete and difficult to maintain. Therefore, a major upgrade of the system was mandatory. It included the substitution of the DC motor by a stepper one and the corresponding IcePAP controller; the replacement of the VME integrators by a state-of-the-art system (either a Keithley or a Keysight nanovoltmeter); and a new control system based on Tango. Also the software was upgraded with the same architecture used in other benches, as sketched in Fig. 7.

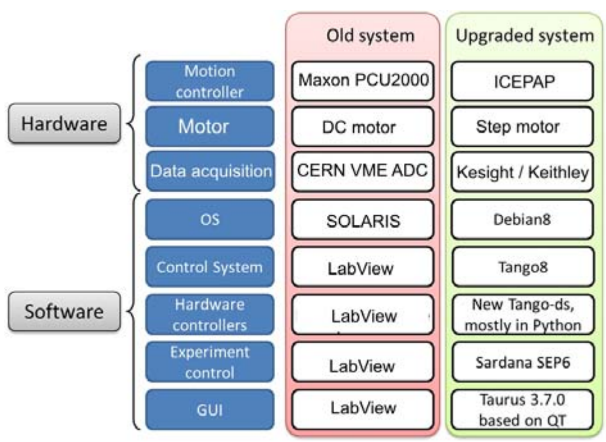

Figure 7: Hardware and Software upgrades of the Rotating Coil bench at ALBA.

In order to test the performance of the new hardware and software we have set up a mock-up integrating the three main devices of a rotating coil: the motor (step motor), the encoder and the coil. For simplicity, the coil is fixed, and the rotary part in the setup is the magnet used as a test. The prototype can be seen in Fig. 8.

Repeatability for the main harmonic is the same than for the old system, as shown in table 3. Further tests will be done to check the repeatability for high harmonics.

Table 3: Repeatability of Rotating Coil Bench

	DC motors	Step motors
Main harmonic	10^{-4}	10^{-4}

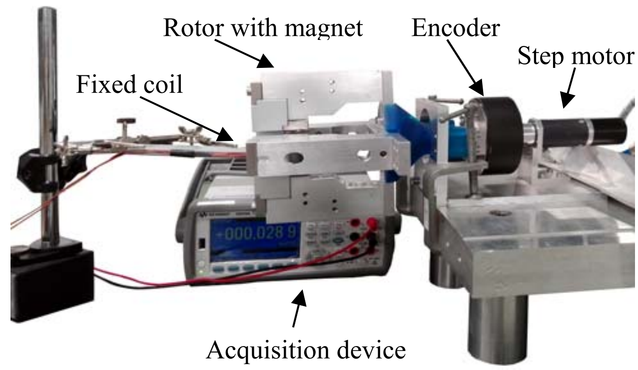

Figure 8: Mock-up of the rotating coil bench used to test the performance of new hardware setup.

CONCLUSIONS

The tests confirm that the step motors are suitable to make magnetic measurement benches requiring continuous movements at constant velocities.

We have successfully upgraded our measurement benches by new devices equipped with step motors without any loss of repeatability. This has allowed the standardization within ALBA of both the hardware (motor models, motor controller) and software (Debian 8, TANGO and SARDANA packages), simplifying accordingly the maintenance and the replacement of parts.

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