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MAGNET MEASUREMENT SYSTEM UPGRADE AT PSI

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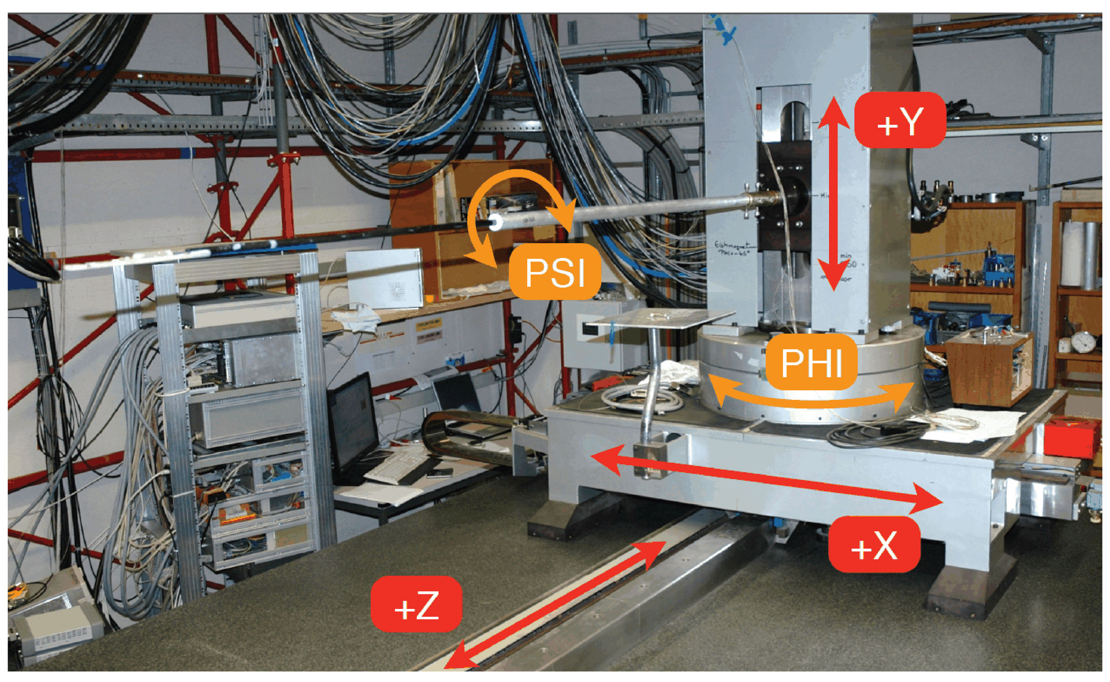
Introduction

The majority of magnets for PSI accelerators and experiments are designed in house and produced by industry. Upon delivery, these magnets are systematically measured to assure that all field quality specifications are met. The measurements are done with the use of the PSI magnet measurement system the technical and operational capabilities of which have significantly advanced in the last months. As a result, it is a modern, automated, user friendly system, which consists of high precision measurement setups based on Hall probe, moving wire, and vibrating wire techniques. The setups are arranged in separate rooms of the PSI magnet measurement laboratory, which are equipped with all necessary measurement tools, control computers, and operational consoles. The magnet measurement system is integrated into the PSI controls, which is based on EPICS. This fact combined with the cutting-edge data acquisition and control software developed for magnet measurement applications at PSI makes the system easy to run not only from local operational consoles but also remotely, eventually from any PC connected to the PSI network.

Hall Probe Setup

Basic magnetic field mapping is performed using Hall probes. Fast automated Hall probe measurements are provided by a computerized Magnet Measurement Machine (MMM) created at PSI.

The MMM is a very precise positioning device sliding on compressed air pads over a flat, carefully machined granite block. Hall probes are attached to a titanium arm with carbon fibre extensions that can move in three translation directions (X, Y, Z) and rotate in the horizontal plane (a yaw angle) and around the arm (a roll angle).



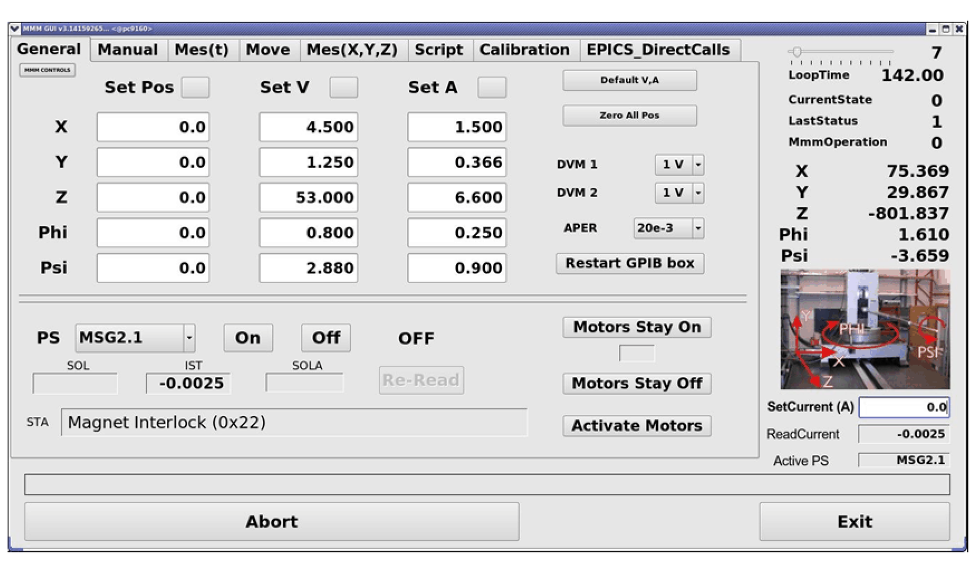
Each move is performed by a dedicated stepping motor. Positions are determined by Inductosyn® linear encoders with one half-micron accuracy. We note that the MMM measurements are performed in any translation direction while two rotations are used only for the proper probe positioning. Therefore, a measured field map corresponds to a line, a plane, or a volume in a Cartesian coordinate system .

Measurements are performed in a continuous scan mode, i.e. the machine doesn't stop to make a particular measurement. With the maximum speed of the machine along the biggest axis (Z), the longest drive takes less than one minute per line and is totally independent of the number of measurement points.

MMM control components

- The magnet current is set by PSI digital power supply (PS) controllers, which are handled by dedicated IPAC (PSC-IP2, VME) modules.
- Hall probe potentials are recorded by the Agilent 3458A digital multimeters or DMM (GPIB). Data triggering is done by an IPAC DIO (Hytec 8505, VME) module.
- Hall probe calibrations are done based on the NMR Metrolab PT2025 teslameter (GPIB).
- Hall probe motion in any of five possible directions is provided by a dedicated stepping motor vis a standard PSI control interface (MAXv-8000, VME).

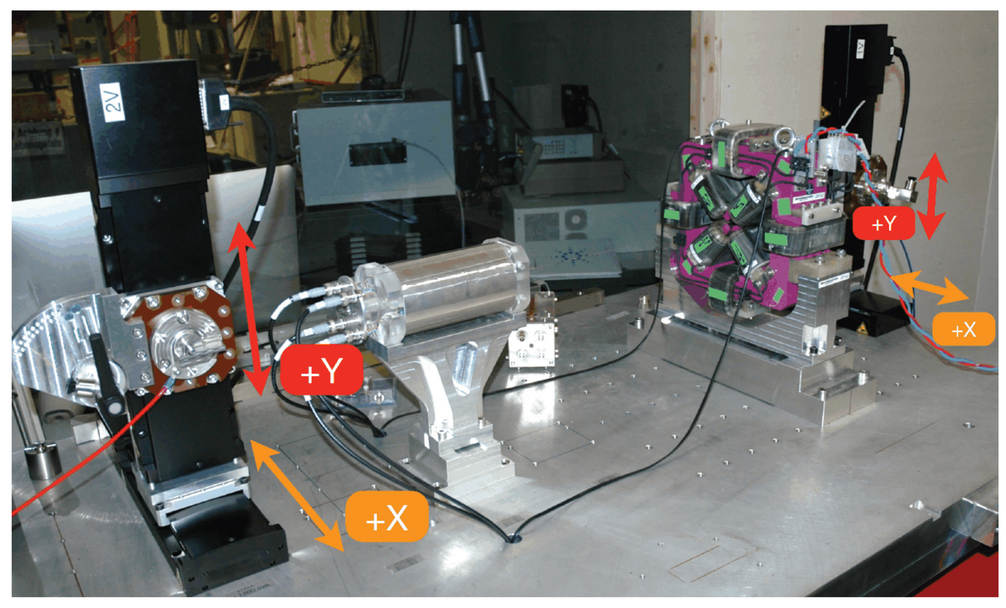
MMM measurements are done with the use of a specially designed GUI tool, which is called mmmgui.
- Based on the Qt toolkit
- Runs on a Linux PC console
- A single user application
- Qt tabs or MMM panels are associated with MMM operational modes
- Handles all data preparation for device triggering at quasi-equidistant measurement points



The most frequently used MMM operation, which is driving a Hall probe along a measurement axis, is supported by the Mes(X,Y,Z) mmmgui panel. The operator has to define the start and end positions of the measurement, the motor acceleration and maximum speed, data acquisition time, the number of measurement points, and the magnet power supply current value. Based on this information, the mmmgui control software performs a series of calculations and system parameter settings. In particular, assuming that the measurement points are equidistant, their coordinates are defined and immediately become a part of the EPICS database. This makes the MMM server software ready to trigger the DMM device exactly when the probe reaches such measurement points. Each time the DMM device is triggered, the actual probe potential is written into its internal memory buffer. When the motion is completed, all recorded data are transferred by the mmmgui software to the computer disk. Simultaneously, the measured probe potentials are written into the EPICS database, which already contains time stamps and probe coordinates corresponding to those potentials. The time stamps are obtained directly from the VxWorks operating system and the probe coordinates are DMA transferred from the VME memory associated with motor encoder data at the moments when the trigger signals are generated. The MMM server software assures all necessary real time constraints on the whole data acquisition process. We note that normally the same line is measured again in the reverse direction before moving MMM to another line. Measuring in both directions helps to cancel positional errors and any voltages induced in the probe connections moving in magnetic field gradients.

Vibrating Wire Method Support

A stretched wire excited by an alternating current (AC) starts oscillating in the static magnetic field. The AC frequencies corresponding to natural wire resonances cause particularly large vibrations, which makes such a system very sensitive to the existence of the magnetic field along the wire. Essentially, when the wire stretched in a multipole magnet stops vibrating, the effective magnetic axis and the wire are aligned. So, to locate the magnet axis, the wire should move until its oscillations vanish. This idea is the fundamental basis of a single stretched vibrating wire method, which is the most accurate technique to define the magnetic axes of multipole magnets.



- The vibrating wire test bench is installed in a separate room, which is not air conditioned, to minimize the air flow. The magnet and air temperature are monitored by the control module developed at PSI (resolution is 0.01º C).
- Electronics is kept outside of this room to make sure that temperature changes during measurements are low and slow.

- Four Newport motorized linear stages move the wire horizontally and vertically. They are handled by SMC100 controllers (RS232).
- Two lock-in demodulators of a digital lock-in amplifier (HF2LI, Zurich Instruments) are used for the vibration detection and two for the wire position detection.

One stage pair is static on a measurement table. The other pair can be relocated, which allows for measurements with different wire lengths. The magnets are placed on the table at the distance of a quarter wire length next to the static stage pair. At the other wire end, the vibration detector is positioned with the equal distance next to the movable stage pair. The reference point positions on the wire supports and the magnets are found with a FaroArm Quantum device. The position accuracy is better than 10 µm. The detection of wire vibrations is done by a novel PSI detector consisting of four pick-up coils, which form two orthogonally positioned pairs allowing one to detect the complete wire vibrations in space. The measurement signal from the pick-up coil pair contains the information about the wire position relative to the center of the coils and about the wire vibration. At that, the position of the wire in the detector doesn't influence the vibration reading and the vibration-induced voltage is virtually independent of the wire current frequency.

Moving Wire Setup

A single stretched moving wire method is suitable for harmonics measurements in multipole magnets. The idea of this technique is relatively simple: move a stretched wire along a cylindrical surface in the magnet aperture and measure the magnetic flux change as a function of the rotation angle.

Main controls components:
- Newport XPS motion controller with advanced trajectory and synchronization features (external triggering).
-Agilent 3458A digital multimeter (GPIB).

A standard EPICS XPS support software package is a part of a special moving wire measurement control tool developed at PSI. The tool consists of a Moving Measurement Control (MMC) application, which runs on a Linux PC, and a set of MEDM GUI panels that are very easy to use for handling measurements. The MMC application communicates with the XPS controller over the computer network. Two pairs of linear motorized stages connected to the XPS controller are configured (as XY groups) to synchronously move both ends of a stretched wire along a specified line or arc, which makes it easy to perform any required plane or cylindrical motion. The MMC application must be provided with a wire trajectory definition file containing a set of reference points through which the system has to move the wire and a number of trajectory points (including start and end ones and assuming that they are equidistant) in which the XPS controller will generate trigger signals for external electronics. Simultaneously with generating a particular external trigger signal, the XPS controller writes the corresponding wire coordinate into its local memory buffer. The XPS trigger signals are caught by a DMM device dedicated to the moving wire setup. This device writes the information about the flux change induced voltage of the moving wire at those moments into its internal memory buffer. The MMC application assures that the DMM device configuration follows the XPS controller settings. When the wire motion along the specified trajectory is finished, the MMC application transfers XPS and DMM device local memory buffers into the EPICS waveform records associated with a 2D trajectory representation and corresponding wire current values, which immediately makes measurement data available for archiving, post processing, modeling, etc.

CONCLUSIONS

An upgraded magnet measurement system has been in successful operations at PSI for the last few months. The system is automated following PSI controls standards. The automation software is implemented as a set of tools supporting Hall probe, moving wire, and vibrating wire magnet measurement setups.

Each tool consists of a main control application handling the measurement process and a set of GUI panels, which are used to run that application and monitor its state. Being a part of the EPICS control environment, the magnet measurement data are very easy to work with. For instance, the data archiving is done with the use of a standard EPICS Archiver. The applications written in popular scripting languages (Python, Lua, Bourne shell, etc.) allow users to efficiently handle magnet measurement processes remotely, perform on-line and off-line data analysis, and generate measurement data reports. Further system developments are going to be concentrated on the design and implementation of EPICS 4 data services, which should organically combine the measurement data, the data processing models, and the data processing results for each particular magnet into a transparently structured data object associated with this magnet.