MOTION CONTROL ON THE MAX IV SOFT X-RAY BEAMLINES WITH TANGO AND SARDANA

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Abstract

MAX IV Laboratory, a synchrotron facility in Lund, has selected TANGO as the control system framework for the entire facility. On the beamlines that are being built the Python-based SCADA (supervisory control and data acquisition) system Sardana will be used for experimental control.

SPECIES, one out of eight new soft X-ray beamlines, is used as a test bench for evaluating the chosen standards. Sardana is used to control the energy setting of the PGM (plane grating monochromator) as well as to provide macros and other utilities for the user. Generic Taurus GUIs and a SVG-synoptic give the user a way to interact with the control system and display relevant information. The standardized graphical interfaces give a familiar look and feel across the entire facility.

All motorized axes are controlled with the IcePAP motion controller. For the axes of the PGM, the IcePAP driver operates in hardware closed loop. Special care is taken in order to avoid slow and inaccurate movements of the PGM energy due to the non-linear relationship between the motors and the angular encoders.

INTRODUCTION

MAX IV Laboratory [1] will be a cutting edge synchrotron located in Lund, Sweden, and it is currently commissioning its main storage ring. This new facility builds on the experience from the previous MAX-lab in Lund, which is being decommissioned after 25 years of successful service to users from all over the world.

At this stage fourteen beamlines are funded and some are already in the process of being assembled at the MAX IV. The first users are expected in 2016. The SPECIES soft x-ray beamline [2, 3] is currently commissioned and taking users at the older facility MAX-lab with the intention to serve as a test bench for the control system that will be used at all the other beamlines at MAX IV.

During the commissioning of the SPECIES beamline, several motorized optical elements needed to be controlled to adjust the alignment of the beamline and its two branches, 40 meter long in total, as seen in Fig. 1. Also, the characteristics of the photon beam must be well known. This is achieved by using a set of macros making calculations from motor positions and current measurements.

MAX IV BEAMLINE CONTROL SYSTEM

By making use of control system standards already in use at other facilities, it is ensured that there are several tools such as pseudomotors, predefined scans and generic GUIs available from the start of the beamline commissioning. For the majority of the motorized axes the motion depends linearly on the corresponding encoder which makes it straight forward to achieve precise closed loop control but the PGM requires more effort which is further described below.

Control System Standards

The control system for the MAX IV facility [4] applies several standards for both accelerators and beamlines, that have been adopted with the aim to make the deployment and maintenance of a complex machine and a large number of beamlines more efficient and also to grant some familiarity to the user community.

Some of these standards are the TANGO Controls toolkit [5], the beamline SCADA Sardana [6], and the PyQt based Taurus GUI framework [7]. The IcePAP motion controller developed at the ESRF [8] has been chosen as a facility wide standard. Other common references and tools have been developed at MAX IV such as the MAX IV unified coordinate system and the SVG-synoptic interface [9].

Tango, Sardana and Taurus are all open source software and, since they have been developed and used at several other synchrotron facilities such as ESRF, Alba, and Soleil, code and experience have been accumulated over time. To deepen the transfer of knowledge and to contribute to the community, MAX IV is a part of the Tango collaboration, the Sardana collaboration, and the IcePAP collaboration [10].

Commissioning with the Control System

During the development a generic Taurus GUI was used to access motors and configure them, to run predefined scans and modify the scan parameters. The generic Taurus GUI is fast to set up and flexible to use. During the progression of the beamline installation and commissioning new panels for each equipment were added as each set of motors was configured. An example can be seen in Fig. 2.

After the commissioning a synoptic like the one in Fig. 3 will replace the development GUI. The synoptic gives a good overview of the beamline based on the physical location of the equipment. It also shows alarm states and allows quick access to detailed panels for all equipment when the user clicks the corresponding icon. Commonly used functions such as acquisition GUIs may also be launched from the synoptic.

MOTION CONTROL

Motion axes at MAX IV, including the ca 60 axes of SPECIES, will mostly be motorized using 2-phase stepper motors controlled by the IcePAP motion controller [11]. Sardana interfaces well with IcePAP and provides the possibility
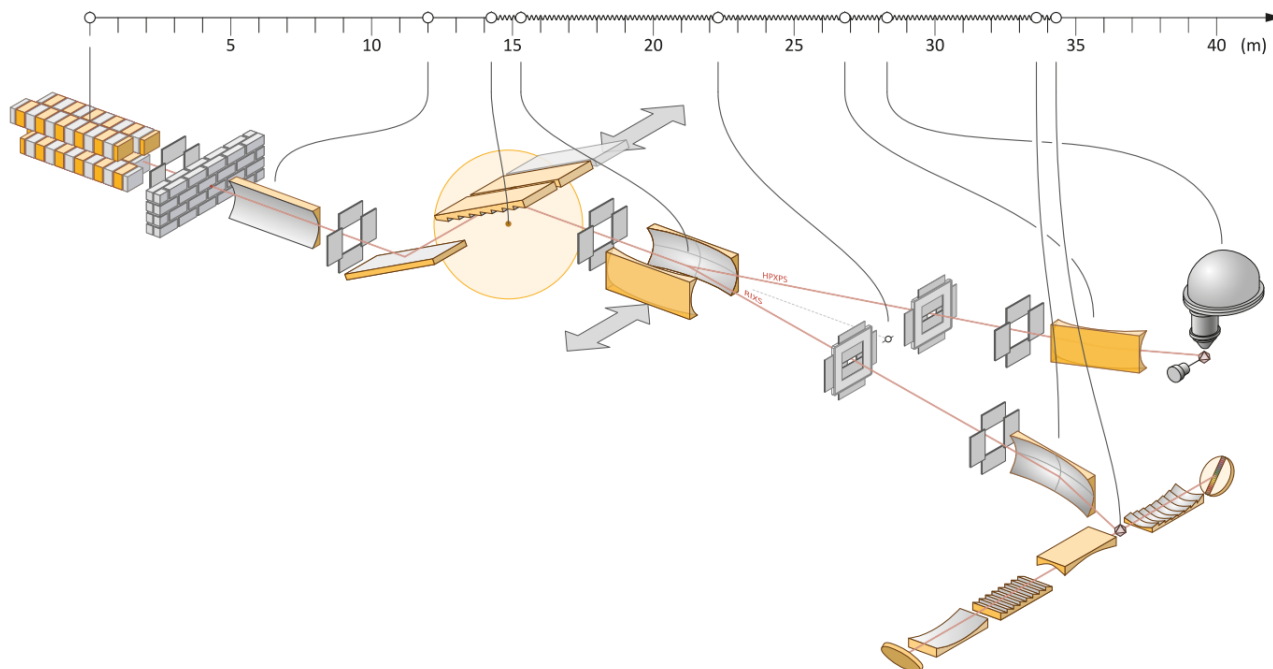
Figure 1: The general layout of the optical elements of the SPECIES beamline showing the main elements that guide the photon beam to the experimental station. Starting on the left: the undulator, a mirror, a set of baffles, the plane grating monochromator, a switching mirror to choose between the two branches, exit slits, more baffles, focussing mirrors and finally the HP-XPS and RIXS endstations.

to define pseudo motors to create complex motions, such as roll, pitch, and yaw, as well as compensate in software for mechanical nonlinearities.

Controlling the Energy of the PGM

The PGM has six motorized axes, but the most important are the mirror axis and the grating axis. On each of those axes, there is a non-linear relationship between the motor steps counted by the stepper motors and the counts of the angular encoders placed on the turning points of the mirror and grating mechanics.

The IcePAP driver operates the PGM axes in hardware closed loop, connecting the encoder signals as positional input to the IcePAP. This is done to ensure that the position is maintained with high accuracy. For the PGM it is important to overcome the non-linear relationship mentioned above, otherwise movements may be slow and inaccurate. The IcePAP accepts only motor steps as input for the desired position, but with a well tuned closed loop and a carefully chosen approximation of the encoder resolution as expressed in motor steps, the motor moves until the encoder value equals the wanted position.

CONCLUSION

Using the control system standards and tools described above we have achieved a stable control system for the SPECIES beamline. Much insight was gained along the way that will be applied for the commissioning of the new MAX IV beamlines.

Results for the PGM Energy

Measurements show a resolution of 0.5 µrad for the mirror and 0.3 µrad for the grating. A one-step movement in closed loop with the highest resolution, including the settling time, takes less than 0.1 ms for the mirror and the grating.

SPECIES' PGM uses RON905UHV angular incremental encoders from Heidenhain. These possess a small well known built in error. The error is visible when the two sine-shaped currents (phase shifted $\pi/2$ rad) from an encoder head moving over one encoder line are plotted against each other. Instead of a perfect circle, the graph is elliptical and offset. The solution is Heydemann correction [12].

In Fig. 4, at the left, this error is visible as a non linear increase in DAQ values during a linear motion. Especially the grating shows this cyclic error, isolated in the right plot in Fig. 4. From the cyclic error in the grating encoder head a correction table was created and each encoder value can now be corrected based on its DAQ value. This correction is implemented in a pseudomotor and the corrected positions are then used to calculate the energy.

To illustrate the performance increase, an N_2 absorption spectrum has been recorded in Fig. 5 and the width of the peaks as well as the distance between them are much more equal with the correction than without, just as expected. The maximum energy correction is 80 meV.
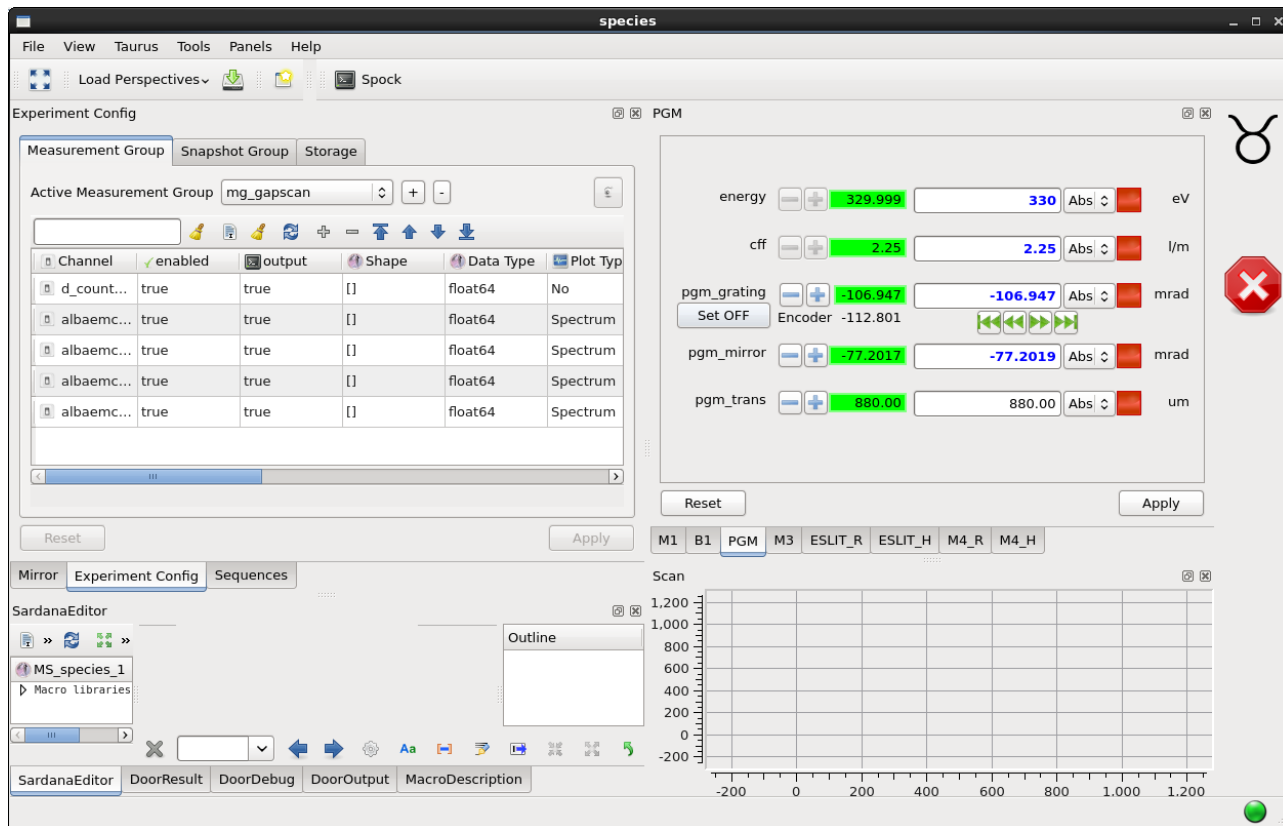
Figure 2: The commissioning GUI is a generic Taurus GUI which allows panels to be added with any combination of equipment and signals available in the control system. In the image above there are panels defined for the motors of each optical element. The GUI is also connected to the experimental control of Sardana.
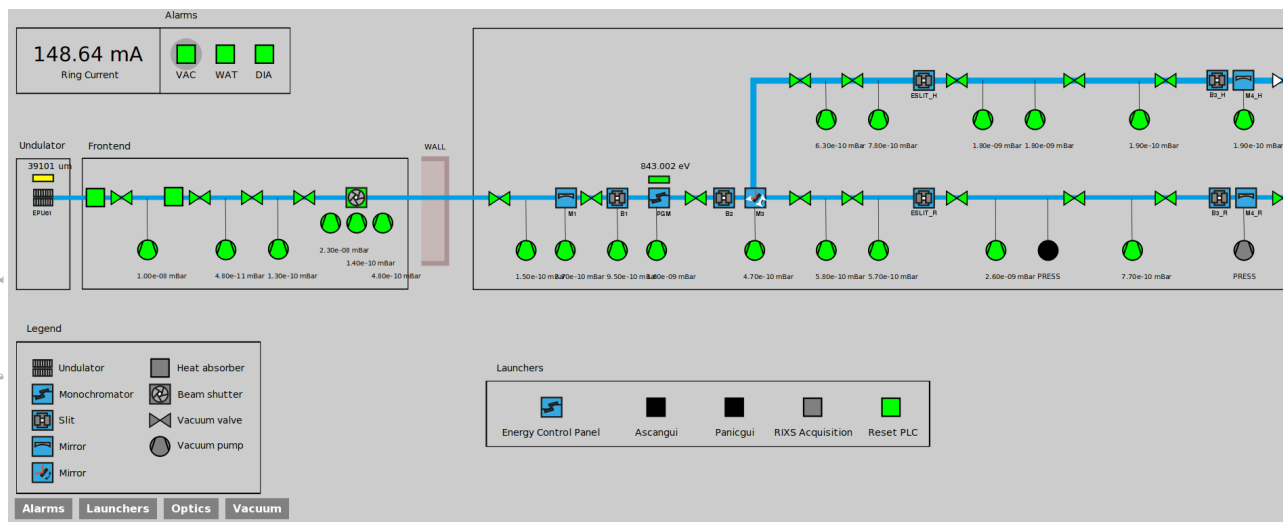

Figure 3: The SPECIES beamline synoptic provides an overview of the entire beamline with the possibility to display information about and control each piece of equipment. The view is defined by an SVG-image which is connected through a Python backend to the control system.
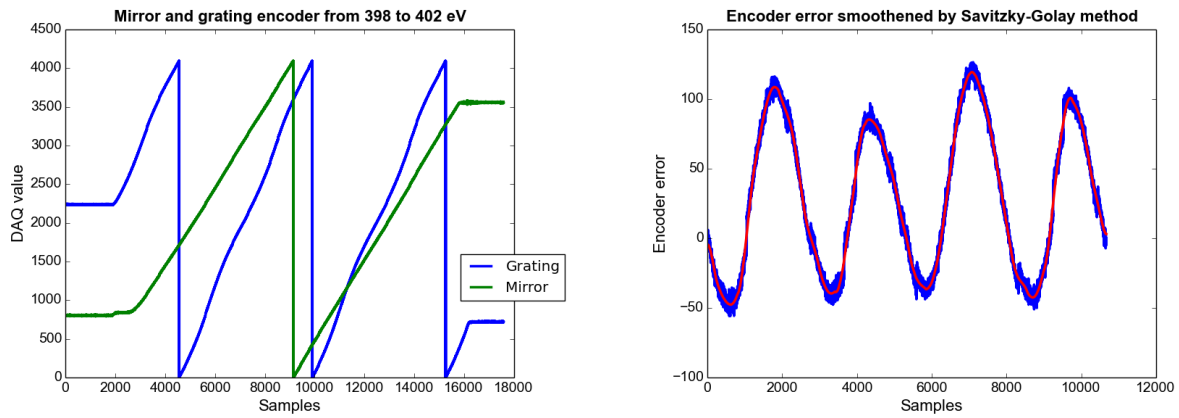
Figure 4: The left plot shows how encoder value increases in a linear motion and it is clear that the grating encoder suffers from a cyclic error. The right plot shows the cyclic error while the encoder passes a few encoder lines.
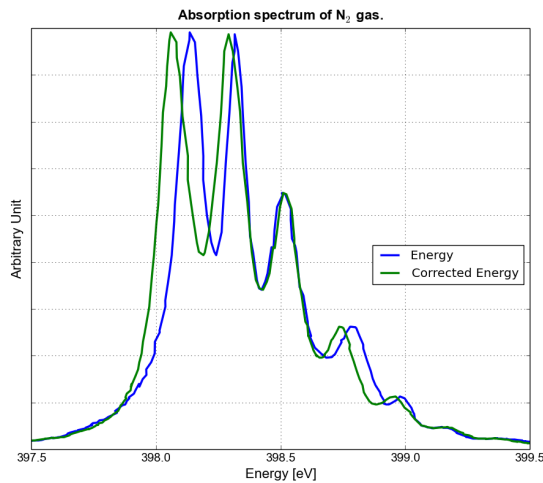

Figure 5: N_2 absorption spectrum with and without energy correction. The maximum correction is 80 meV.

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