UPGRADE OF THE EUROPEAN XFEL PHASE SHIFTERS

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Abstract

To eliminate the impact of radiation shower on the incremental encoder readout and provide a better dynamic movement the upgrade of all phase shifters of the European XFEL have been successfully done without interruption of the operation schedule. The implementation steps, as well as the results of the hardware and software tests made in the laboratory, are presented. The sensitivity of the Renishaw RGH22O15D00A encoder to the radiation shower was measured in the SASE3 undulator system, and the results are presented.

Introduction

From At the European XFEL undulator systems 88 gap variable phase shifters are in use. They had been equipped with the “Oriental Motor” stepping motors and “Renishaw” linear incremental encoders. To bring the phase shifters into the operational state, the homing procedure was required for the linear incremental encoder. During the operation in the tunnel under the beam condition, at some undefined state, the counts of the encoder have been randomly lost. This effect has not been observed during the tests performed in lab. To bring then phase shifters back into the operational state, the rehoming procedure must have been done, which was breaking the operational routine. Additionally, in the coupled mode at the small undulator gaps the phase shifters have been stuck during the movement because of the speed limitation of the stepping motor.

Based on the experience, gained during the first operation of the phase shifters in the tunnel, the decision has been made to build a test setup using the Beckhoff servomotor with the integrated absolute rotary encoder instead of the old stepper motor to create a solution, which will avoid future operational difficulties of the upgraded phase shifters.

Hardware Upgrade

For the phase shifter upgrade the following main steps were performed:

- Exchange of the motor with the bearing,
- Upgrade of the intersection control rack (ICR),
- Integration of the servo axis in the undulator local control system.

The ICR has been modified in order to operate the phase shifter with the “AM8122-0F21-0000” servo motor instead of the old stepping motor. The following hardware components have been uninstalled from the ordinary ICR during the upgrade.

Upgraded Intersection Control Rack

Although the servo motor is equipped with the integrated absolute rotary encoder, which is an indirect gap measurement system, the functionality of the existing feedback system based on the incremental linear encoder has been retained and used as a reference direct gap measurement system, to be able to make the initial calibration of the indirect gap measurement system. All related hardware and connections remained identical to the ordinary ICR.

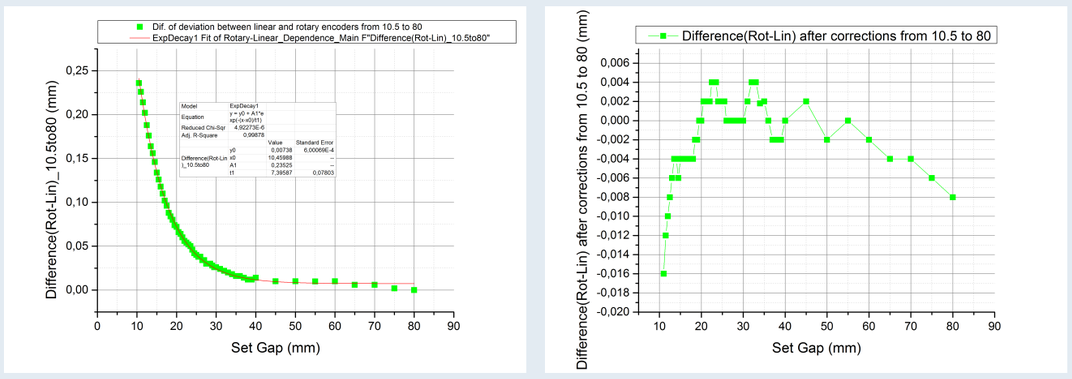
Software Upgrade

- The servo axis has been implemented in the system manager configuration instead of the stepping motor axis in order to operate the upgraded phase shifter. To keep the functionality of the existing linear encoder as a direct gap reading system one more special type of axis has been created named “Linear Encoder”. This axis is not involved in the motion system and was only used later as a reference direct gap measurement feedback system for the correction curve calculation.
- The PLC project has been redesigned in order to operate the upgraded phase shifter.
- The special software called Correction Coefficient Calculator (CCC) has been developed to operate the phase shifter automatically depending on the configuration file in which the sequence of the gap values, speed of the movement and the number of iterations can be specified. Depending on the content of the configuration file, the output file is created. The reason of this activity to measure the gap dependent deformation by comparison of the direct and indirect gap measurement system values. The resolution of the set gap values depends on the gap region.
- In-house developed software solution namely Image Distribution and Automation(IDA) was heavily used during the configuration of each cell’s PLC software with its own parameters such as correction coefficients and position bias.

First Operation of the Upgraded Phase Shifters, Measurement Results

Gap dependent deformation

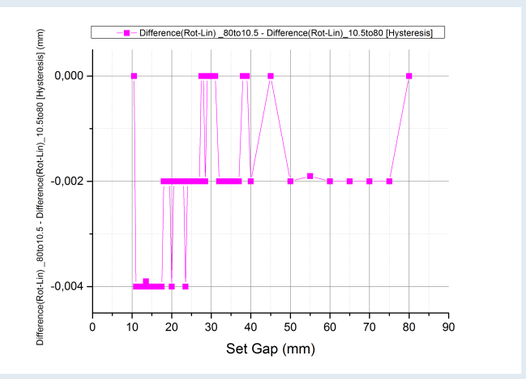
Due to the gap dependent magnetic force which appears between upper and lower girders of the phase shifter, the frame is experiencing also corresponding gap dependent deformation. So called gap dependent correction coefficients have to be calculated and taken into the account because of the indirect gap measurement system, which is involved in the operation of the upgraded phase shifter. The CCC software for each phase shifter has been used to measure the gap depended frame deformation. The data have been analyzed and the gap dependent lookup table has been created, which later was implemented in the PLC project as a correction lookup table for the rotary encoder. The subtraction of the rotary and linear encoders values as a function of the set gap before and after applied corrections are presented on the following figure.



The difference of the rotary and linear encoders values as a function of the set gap before (left) and after (right) applied corrections

Hysteresis study

After the implementation of the correction coefficients the study of the upgraded phase shifter gap positioning accuracy and reproducibility has been done. This study has been performed in order to investigate the gap positioning accuracy by operating the phase shifter with indirect gap measurement system, namely absolute rotary encoder. In order to measure the actual hysteresis, the same CCC software have been used. The only difference was the scanning has been done first downwards from 80 mm till 10.5 mm gap and then backwards to 80 mm in one scan.



The difference of downwards and backwards scanning mode after applying the correction coefficients

Conclusion

The planned modification of 107 phase shifters with the ICRs using servo motors and absolute encoder feedback was done for all tree SASE undulator systems without interruption of the operational schedule. The following main results have been achieved during tests performed in the lab:

- A maximum difference of 16 µm deviation between the rotary and linear encoders values has been measured after applying the correction coefficients,
- The maximum observed hysteresis of 4 µm has been detected,
- Servo motors significantly improve operational functionality and increase the motion dynamic range,
- In the coupled mode the phase shifter axis shows the good repeatability of the gap positioning and follows the undulator axis,
- The lag distance is depending on the undulator axis speed, and it’s practically negligible if the undulator axis speed override value is set to 0.1%,
- After the modification campaign, the significant increases of the phase shifters operational reliability was observed during the last nine-month of the facility operation. Besides the reliability, the time-saving aspect is another valuable improvement which is crucial while changing the undulator system parameters.

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