INSTALLATION AND HARDWARE COMMISSIONING OF THE EUROPEAN XFEL UNDULATOR SYSTEMS

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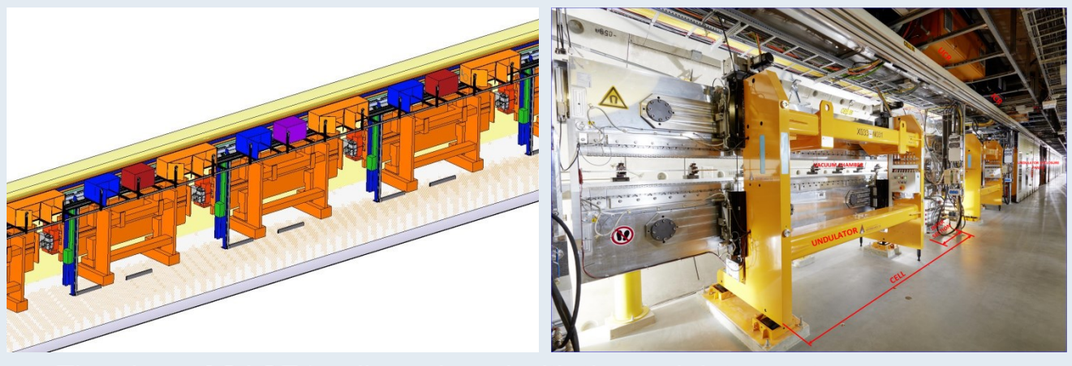
Abstract

The detailed description of hardware installation and commissioning of components for undulator systems at European XFEL is presented. In general, the work can be divided into 3 different steps: installation, alignment, and commissioning. During installation step, the following main components were rolled into the tunnel: - undulators with the control cabinets, intersection control cabinets, phase shifters, quadrupole movers, correction coils. They have been mounted according to the designed positions. Then all mentioned components have been aligned according to the specifications. Finally, the cabling has been done and basic tests were performed. As part of the commissioning, the calibration of the temperature sensors, as well as the measurements of the quadrupole mover travel distance has been done in the tunnel. Afterwards, the undulator limit switches and hard stops were adjusted to secure the vacuum chamber by closing the undulator gap up to 10mm. Eventually, the system was handed over to the global control system in order to perform all functional tests. The main focus is given to the components which are controlled or monitored by the undulator local control system .

Motivation

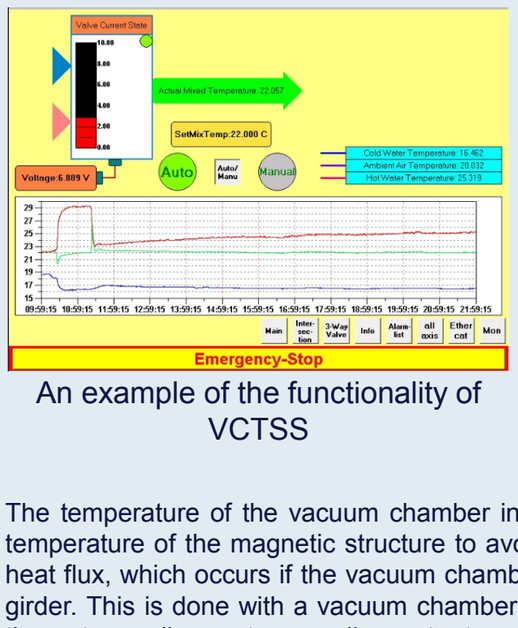
- From the sketch to the real system



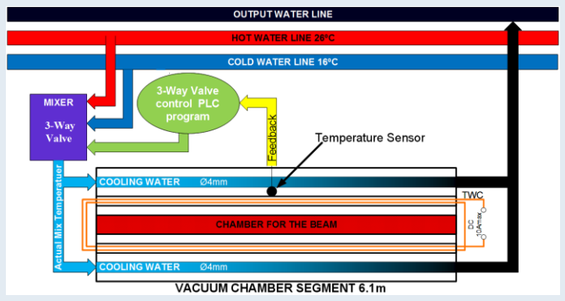
The view of SASE1 cell, equipped with the undulator system components: vacuum chamber, undulator, intersection, UCR and ICR.

The European X-ray Free-Electron Laser (XFEL) will be operated by using tree undulator systems based in total on 91 variable gap undulators. The SASE1 system is commissioned, it is in operation and delivering the photon beam to the experimental hall with the following parameters: 300muJ, 9.3keV up to 30 bunches, for the FXE (Femtosecond X-Ray Experiments) and the SPB/SFX (Single Particles, Clusters, and Biomolecules and Serial Femtosecond Crystallography) instruments. The first lasing has been achieved in May 2017. The SASE3 undulator system is commissioned and ready for the operation which will start in October 2017. The last SASE2 system is currently installed in the tunnel and will be commissioned by the end of the year 2017. All three systems are designed in the same fashion, and installation sequence of actions is identical for all three undulator systems: SASE1 (Self-Amplified Spontaneous Emission), SASE2 and SASE3. The description of SASE1 system is presented.

Vacuum Chamber Temperature Stabilization System (VCTSS)



An example of the functionality of VCTSS



Schematic view of the parallel water connection scheme and the control system of the mixer. The coil of Two wire connection system is also shown.

The temperature of the vacuum chamber in the undulator gap needs to be identical to the temperature of the magnetic structure to avoid the girder deformation due to the transverse heat flux, which occurs if the vacuum chamber is at a different temperature than the magnet girder. This is done with a vacuum chamber water cooling system. For efficient operation of the water cooling system, cooling water temperature is stabilized within the accuracy ±0.1°C.

Installation of the Undulator System Components

Before being installed in the tunnel all hardware components have been commissioned and validated in the laboratory by performing the number of tests. The SASE1 (Self-Amplified Spontaneous Emission) undulator system contains of 37 sections, so called cells. Each typical cell includes an undulator and an intersection. Only first two cells are not equipped with the undulators. This scheme has been realized for the future evolution of the SASE system by implementing the self-seeding feature. The main components are:

- **Undulators** The photon beam is produced by means of the undulator system. The undulator system consists of an array of undulator cells installed in a row along the electron beam. The undulators are designed based on gap variable planar hybrid undulator technology.
- **Phase Shifters** For gap adjustable undulator systems, phase shifters are needed to adjust the phase between electrons and photons field. The phase shifter is based on permanent magnet technology
- **Quadrupole Movers** The control of the quadrupole magnet mover is a part of the local undulator control system. Information about the quadrupole magnet corrections or the set values in horizontal and vertical directions is obtained from the beam positioning system
- **Correction Coils** To ensure self-amplified spontaneous emission process the undulators must not deflect the electron beam from its orbit. The possible deflection of the electron beam, introduced by the undulator, is corrected by means of upstream and downstream correction coils. They are eliminating not only the deflection angle, but also the displacement between electron beam trajectory and the orbit.

- **Undulator Control Racks (UCR)**
- **Intersection Control Racks (ICR)**
- **Intersection Control Nodes (ICN)**
- **Media Convertor Racks (MCR)**

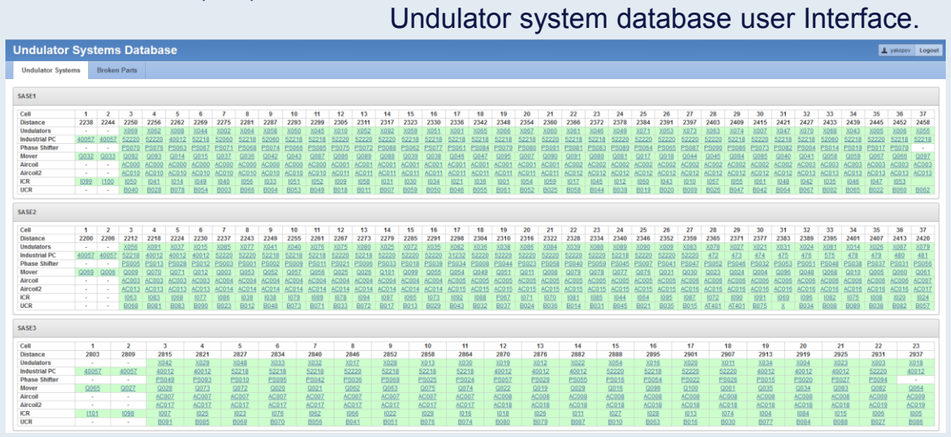
All mentioned racks are parts of the undulator control system, which is based on the real time Beckhoff automation technology. The PLC program is implemented in the TwinCAT system and running on the Industrial PC (IPC's) installed in the UCR's

Commissioning of the Undulator System

A number of the Supervisory Control and Data Acquisition (SCADA) software have been developed and successfullyy used during the commissioning phase:

- Undulator System Database
- Image Deployment Automation (IDA)
- SASE tester

Undulator system database user Interface.



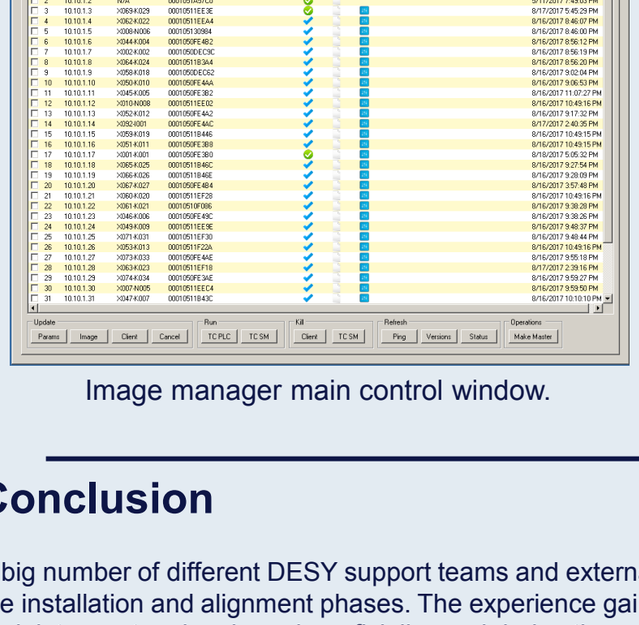
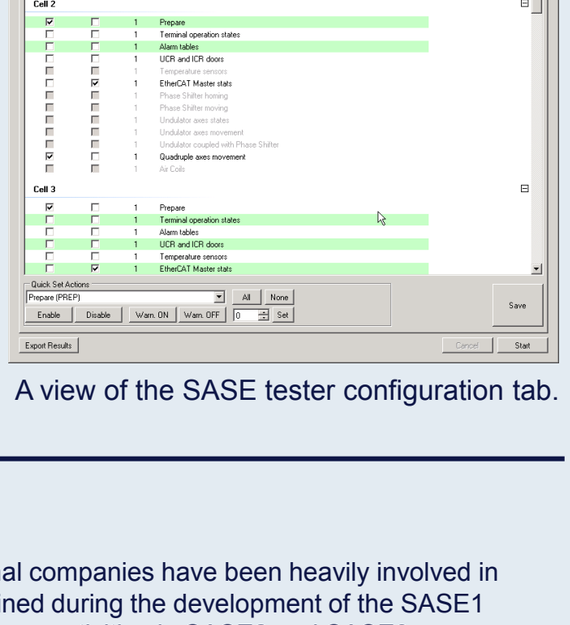


Image manager main control window.



A view of the SASE tester configuration tab.

Conclusion

A big number of different DESY support teams and external companies have been heavily involved in the installation and alignment phases. The experience gained during the development of the SASE1 undulator system has been beneficially used during the same activities in SASE2 and SASE3 undulator systems.

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