OVERVIEW AND STATUS OF THE SWISSFEL PROJECT AT PSI

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Abstract

Recently, the installation of the components for the free electron laser SwissFEL has started at the Paul Scherrer Institute (PSI). In March 2016, beginning of the injector commissioning is planned and first lasing is foreseen a year later. New hardware, like VME64x-boards (IFC 1210, an P2020 based intelligent FPGA controller from IOxOS) and -crates (Trenew), timing system (from MRF with advanced features), motion controllers (Power PMAC from Delta Tau, and MDrive from Schneider), among others, as well as modern field buses, pose great challenges to the controls team. The close interaction of machine- and experiment-components require advanced software concepts for data-acquisition, -distribution, and -archiving. An overview of the project will be presented and the different HW and SW solutions based on the experience gained from preliminary implementations at other facilities of PSI will be explained. First results of the HW commissioning at the SwissFEL will be reported.

INTRODUCTION

The Paul Scherrer Institut (PSI) is the largest research centre for natural and engineering sciences within Switzerland and is located northwest of Zurich, about an half hour’s drive away. Research is performed in three main subject areas: Matter and Material; Energy and the Environment; and Human Health. For this fundamental and applied research we use three different accelerator facilities on site and support additional test facilities:

- The facilities consist of one of the highest intensity 570 MeV proton cyclotron, HIPA, that produces particles for fundamental particle physics, muons, and is the source for the neutron spallation source SINQ.
- Another low energy superconducting proton cyclotron is used for the patient treatment systems at the Center for Proton Therapy.
- The Swiss Light Source, SLS, is a 3rd generation synchrotron and houses 18 beamlines.

These accelerators are available for the international community; we host about 2400 external users per year. All these facilities are controlled from a central control room.

Until the end of October 2014 a 250 MeV electron Linac, SITF (SwissFEL Injector Test Facility), was in operation and was used as a pre-study for the free electron laser (FEL) project. Many of its components are used as the injector for the upcoming FEL. The new SwissFEL is currently set-up a few hundred meters east of the main campus of PSI.

Of course, there are several other test-facilities and laboratories related to the accelerator facilities.

This large array of different facilities and set-ups around the laboratory poses quite a challenge to be handled by one Controls group. Therefore a lot of emphasis has been put on standardization on the equipment that is supported and the tools that are being used within the Controls group. However, there are new experiments and test set-ups constantly coming up that need to be supported on the one hand, on the other one has to watch a growing heap of legacy components and code that have to be maintained. E.g. HIPA is operational since over 40 years.

Standardization in the Past

In order to minimize any overhead and maximize the efficiency of the Controls group a strong standardization effort is implemented. Among these standards are: All accelerator and most control systems are based on EPICS [1]. For fast I/O, scalers, etc. we use a VME bus architecture, controlled by a Motorola CPU board running VxWorks 5. The timing system is based on the model 230 of Micro-Research Finland [2]. The main motion controller used is MaxV from Pro-Dex.

Consoles and most servers run Scientific Linux 6.4 and the Linux software is distributed through Puppet. To deploy software for the EPICS system a mechanism developed at PSI is used. A relational database keeps an overview of our hardware inventory and helps in managing the many components at the facilities.

THE SWISSFEL PROJECT

The new SwissFEL is currently set-up a few hundred meters east of the main campus of PSI (Fig 1). The project consists of two consecutive phases.:

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- In the first phase (from 2013-2016) a compact hard x-ray free electron laser with one beamline and 2 planned endstations in the 1 Å range will be build.
- In a second phase a low energy branch will be added to produce soft x-rays.

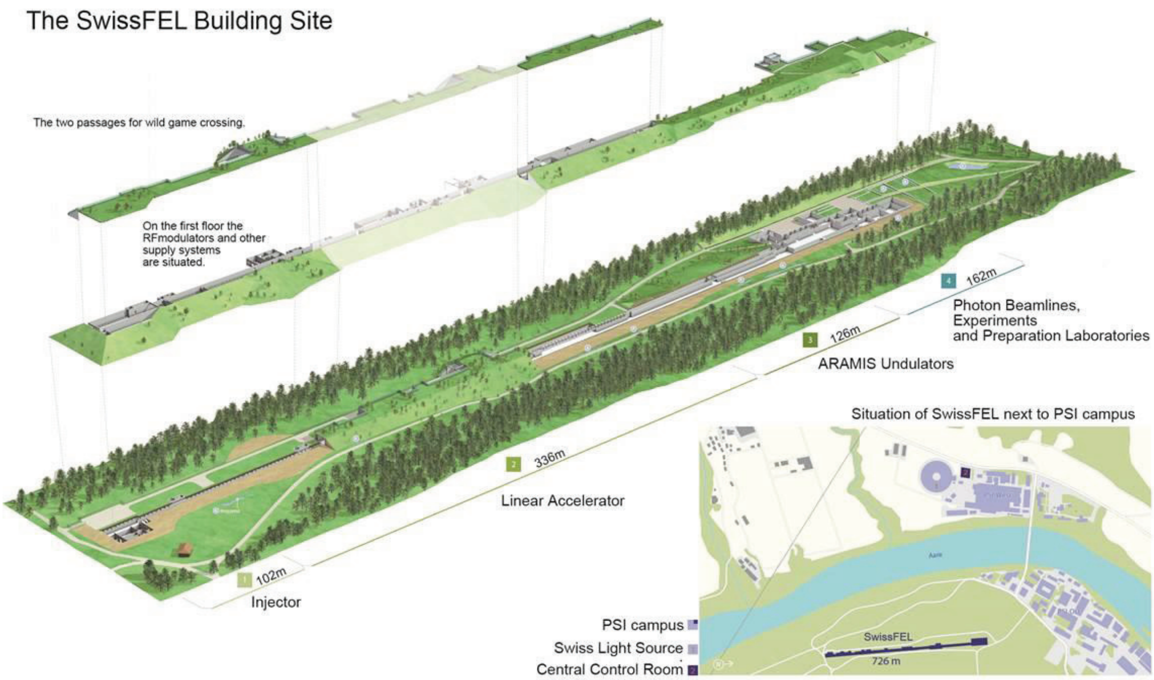

Figure 1: The SwissFEL building site.

The machine itself is housed inside a tunnel roughly at ground level. On top of it the technical gallery is located. The facility is 720 metres long and composed of four sections. The injector with a 3 GHz RF gun, a linear accelerator with 26 C-Band RF modules, an arrangement of 12 planar undulators, and the photon beam line and experimental facilities. So far financing of two user endstations is secured, but a third one is planned.

The key figures of the facility are listed in table 1. The accelerator will be operated in mainly two modes, one with a long pulse of 25 fs length and a charge of 200 pC resulting in a photon intensity of $7x10^{10}$ and a short pulse length of 6 fs with a 4 times lower photon intensity at a photon wavelength of 1 Å.

Table 1: Key parameters of the SwissFEL

Overall Length	720 m
Total electrical power	5.2 MW
Maximum electron beam energy	5.8 GeV
Number of FEL lines	2
Wavelength	1 - 7 Å, 7 - 70 Å
Repetition Rate	100 Hz
Number of Endstations	2 + (1)
Cost	278 MCHF

Installation of the machine components started in September 2015 and the installation of the control system components started at the end of October. Beam commissioning of the injector will start in April 2016, and that of the Linacs about a half year later. First lasing is expected at the beginning of 2017 with users starting to use the facility in fall of 2017.

The PSI Controls group will be responsible to enable the remote operation from the main control room for the accelerator as well as the control of the experiments from their dedicated control rooms (inside the SwissFEL building).

NEW REQUIREMENTS

The new facility poses quite a few new challenges due to new requirements. These are somewhat related:

- Going from circular to a long linear machine means a **highly distributed** system. This results in smaller VME crates and additional bus systems, like EtherCAT, that have to be supported. In addition the SwissFEL will be further away from the main control room than all other PSI facilities. This results in the wish to have remote control over even the smallest devices like power strips.
- SwissFEL is a pulsed machine and therefore a stable, and **reliable timing system** is crucial.
- Due to the pulsed nature and large extend of the machine recording of data has to be **synchronized** by tagging each datum with an event pulse number.

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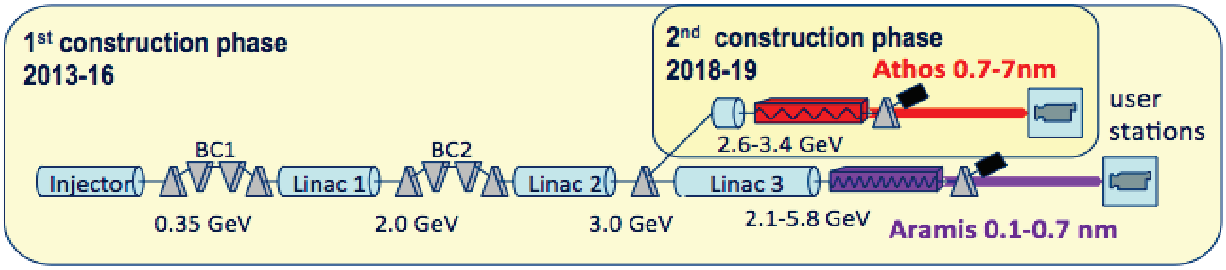

Figure 2: Overview of the SwissFEL accelerator.

- New detectors and high performing cameras produce **large amounts of data**. This calls for a high network bandwidth and new, as well as efficient ways of data-acquisition systems.

FUTURE STANDARD SOLUTIONS

Due to the new requirements and the age of some of the current standards at the other facilities there need to be new solutions for SwissFEL

Network

Throughout the facility there will be 10 Gbit Ethernet networks using copper and glass fibre. A 100 Gbit-connection is available between the main switch of the SwissFEL building, the ones of control room and the two computing centres of PSI. Two 100 Gbit lines a reserved for camera data going directly to the control room.

The usage of EPICS gateways to separate the different parts of the SwissFEL facility has proven to be problematic during tests at the SITF. Therefore we will start with a flat network structure.

VME-Crates

Much care went into the specification of the 7 slot-crates concerning reliability, low noise level on the power lines, and a remote control and monitoring capabilities. The latter is based on an I^2C protocol. The data and control are available in EPICS through the stream device driver [3]. The crates are provided by Trenew.

VME Bus and FPGA Controller

The board of choice for the VME bus controller is the IFC 1210 from IOxOS SA, Switzerland and was designed in a collaboration effort between the controls and low-level-RF groups of PSI and IOxOS. It is a 6 U VME64x single board computer containing a Freescale Power PC P2020 dual core and Xilinx Virtex-6 central and Spartan-6 IO FPGAs. Extension slots allow the insertion of 2 XMC, 1 PMC, or 2 FMC mezzanine cards. As an operating system RTLinux is used.

The IFC 1210 is used for fast D/A signal processing, timing, Power-Supply control and connection to EtherCAT-Systems. About 250 boards will be deployed at the SwissFEL.

Timing and Event System

This system is based on the new 300 model from Micro-Research, Finland [2]. Event masters come in a VME form factor and the receivers are available as VME and PCIe. The latter ones are used in the Windows systems that read-out the cameras along the facility, in the Linux systems for the detectors, and in the motion controllers that need a synchronized movement, e.g. Wiresanners. The system runs internally at 142.8 MHz which results in a resolution of 7 ns. Finer time-shifts can be obtained from dedicated delay modules. The system shows a low RMS jitter of 5 ps. The new system is capable of delay and drift compensation that is caused through the whole path of the event transmission between the master and each receiver due to different path lengths and local temperature variations. It allows the instant modification of the sequence of the event stream during each shot of the SwissFEL. The system is used to synchronize the different processes at the facility with high precision and is crucial for the data-acquisition. Instant delay shift mechanism is another new feature that is crucial for the machine protection system (MPS).

The EPICS driver has been updated recently, to take advantage of the new functionalities of the novel hardware.

Motion Control

For coordinated, as well as synchronized movements, motors are controlled through the PowerBRICK based on the PowerPMAC system of DeltaTau.

Regular movements are done with the help of MDrive system from Schneider Electric. They come with the power driver directly attached to the motor chassis and provide an Ethernet connection as a communication interface. A system without this interface is also available from Schneider Electric called MForce. For this an in-house power driver has been built and allows to control up to eight axes.

The EPICS motor record has been updated to include the new functionality of the hardware.

Camera Systems

For diagnostic, monitoring and alignment many cameras will be used at the SwissFEL. Up to five high-performing PCO cameras running at 100 Hz will be running during the operation of the accelerator. For

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reduced needs like beam or laser alignment cameras from Basler will be used.

All of them will be connected to Windows servers that allow first image analysis, provide the camera control in EPICS, do event tagging of the images with a PCIe event receiver, and distribute the images if needed with 100 Hz (the beam repetition rate).

Serial and Low Demand Systems

For slow control and I/O like temperature, switching, etc. we provide different serial interfaces. Among these are Wago [4] and Moxa [5]. Work has also gone into interfacing EtherCat into EPICS [6], as there are needs to enable real time communication with Beckhoff PLCs [7]. This will be used for example to control the RF modulators in synchronisation with the Low Level RF to change phase and amplitude of the acceleration.

Beam Synchronous and High Volume DAQ

New detectors like Jungfrau or Gotthard will be used at the beamlines and experimental station. These 1- and 2-dimensional detectors produce large amounts of data. Furthermore, additional data that reflect basic accelerator parameters are needed to describe the current pulse for the experiments. To handle these requirements a new DAQ had to be developed. Details can be found in several contributions to this conference [8].

CONCLUSION

The SwissFEL facility introduces new requirements and challenges to the Controls group of PSI. All of them could be met with new standards in hardware or in software. Controls will be ready for beam commissioning of the SwissFEL injector that starts in March 2016. For the other PSI facilities we will gradually replace the old standards with the new ones were appropriate.

ACKNOWLEDGMENT

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REFERENCES

[1] EPICS website: http://www.aps.anl.gov/epics/

[2] Micro-Research Finnland website: http://www.mrf.fi/

[3] EPICS stream device driver website: http://epics.web.psi.ch/software/streamdevice/doc/

[4] WAGO website: http://www.wago.com

[5] MOXA website: http://www.moxa.com/

[6] D. Mayer-Manojlovic, "",MOPGF027, these proceedings, ICALEPCS2015, Melbourne, Australia (2015).

[7] Beckhoff website: https://www.beckhoff.com/

[8] S. Ebner et al., „Data Streaming - Efficient Handling of Large and Small (Detector) Data at the Paul Scherrer Institute",WED3O06, these proceedings, ICALEPCS2015, Melbourne, Australia (2015).

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