CURRENT STATUS AND PERSPECTIVES OF THE SWISSFEL INJECTOR TEST FACILITY CONTROL SYSTEM

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Abstract

The Free Electron Laser (SwissFEL) Injector Test Facility at the Paul Scherrer Institute has been in operation for more than three years. The Injector Test Facility machine is a valuable development and validation platform for all major SwissFEL subsystems including controls. Based on the experience gained from the Test Facility operations support, the paper presents current and some perspective controls solutions focusing on the future SwissFEL project.

INTRODUCTION

SwissFEL is a linac driven free electron laser, which will be built at the Paul Scherrer Institute (PSI), Switzerland in the next few years [1]. The machine will generate high-brightness photon beams covering 0.1–7 nm wavelengths. To minimize the SwissFEL length and, as a result, its final costs, the project aims to use the lowest electron beam energy compatible with 1 A operation, which is very challenging and requires the development and implementation of advanced technological solutions for generating, compressing, and transporting high quality electron bunches.

The SwissFEL Injector Test Facility (SITF) is a highly flexible 250 MeV linear electron accelerator that has been in operations at PSI for more than three years [2]. The facility consists of a laser driven RF gun, which is followed by an S-band booster section, a bunch compression area and a diagnostics section featuring an RF deflector and a series of FODO cells for the beam emittance control.

In order to facilitate a very rapid deployment of control applications needed by the SITF project, its control and data acquisition system was initially based on the Swiss Light Source (SLS) concept [3]. At the same time, a lot of effort was put on new developments, which significantly expand the possibilities of the existing control system and form a strong basis for dealing with current and future PSI projects including the SwissFEL.

CONTROL SYSTEM OVERVIEW

The SITF control system is based on EPICS [4].

The basic element of the computer network is a C class subnet. Since the number of needed network ports is too high to fit into one subnet, the connections of different subnets are handled by EPICS Channel Access (CA) gateways, dedicated computers running special software to minimize network data traffic. Unfortunately, the existing CA gateway implementation suffers from two major problems. It crashes unexpectedly from time to time without any error log information. It also introduces a few seconds delay when transferring megabyte data arrays from CA servers to client applications, which are on different network segments. It is obvious that in this state the CA gateway can't be used for the SwissFEL project and must be either improved or rewritten from scratch. The PSI controls team is currently working on new CA gateway software. Its pilot version was recently tested at the SITF. Test results are very promising. At the same time, class B subnets are under consideration for the future SwissFEL controls network topology.

The controls equipment connects to the control system mainly via VME crates, which follow the VME64x standard. About 50 VME crates are installed in the facility.

The basic type of the VME CPU (IOC) is a single board computer MVME-5100. It is a reliable solution for most controls applications. At the same time, its limited computational and memory resources make it difficult, for example, to perform fast data acquisition and advanced data processing directly on board.

A crucial role in SITF applications belongs to the timing and event distribution system, providing triggering mechanisms and supporting a synchronous and reliable transmission of all machine critical data. The system is based on Micro-Research Finland global event distribution products [5], the latest generation of which supports real-time data transfer parallel to the event distribution. The required timing information for users is provided by VME and PCI event receiver cards. The system is fully integrated into EPICS, which makes all its functions easily accessible.

We note that the SITF machine nominal rate is 10 Hz but some its subsystems (i.e. lasers) require triggering at 100 Hz. That is why the event generator sequencer is programmed at 100 Hz, which immediately makes the SITF timing system ready for the future SwissFEL project. We also note that SITF timing system capabilities have enabled us to realize a beam-synchronous data acquisition system for on-demand pulse-to-pulse correlated studies of the machine behaviour.

The majority of general purpose ADC, DAC, and DIO control signals are handled by Hytec Industry Pack (IPAC) modules sitting on VME carrier boards. EPICS device drivers for this hardware are mostly written at PSI. The IPAC solution works very well for moderate signal frequencies (up to few hundred kHz) and covers a significant amount of controls projects including numerous laser and beam diagnostics applications.

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ISBN 978-3-95450-139-7

For handling fast (100 MHz and higher) ADCs, a Generic PSI ADC Carrier (GPAC) approach [6] seems to be very efficient. GPAC carrier boards provide a generic interface to the control system. Their FPGAs are programmed to digitize measuring signals with the required time delay and period (which is especially important for gated signal measurements) and to dump the resulting data arrays into the VME memory. That memory can easily be accessed by EPICS records with the use of the PSI General Purpose Memory Mapping (GPMM) driver. We note that the GPAC approach is successfully implemented for BPM and synchrotron radiation spectra analysis applications at PSI.

The principal PSI platform for motion control applications is the VME MAXv-8000 motor controller [7], which supports a wide variety of stepper and servo motors. The access to absolute and incremental encoders is provided via either MAXv transition modules or special encoder counter boards designed by Kramert GmbH [8]. A standard EPICS motor record is setup to efficiently handle motors remotely. Unfortunately, the MAXv solution doesn't fit a highly distributed SwissFEL infrastructure. Therefore the controls team is currently looking for alternative platforms including EtherCAT based and stand alone motion controllers.

Various non-VME solutions were also evaluated for meeting SwissFEL requirements and making use of new controls technologies.

In particular, image capturing and acquisition systems were initially oriented on FireWire cameras. More than 40 cameras of this type were installed in the facility, mainly for diagnostics screen monitoring systems. Such cameras are interfaced to EPICS via Linux PC servers. In spite of lots of work on the improvement of the FireWire camera system stability, its frequent malfunctioning is the main issue for SITF operations. Every week at least two cameras occasionally stop working, which requires resetting them and restarting their servers. The development of new robust video camera controls platforms, which are based on very popular Gigabit Ethernet (GigE) and Camera Link standards, is ongoing. A few new camera systems have been in operations at PSI for more than one year and appear to be good candidates to replace problematic FireWire setups.

Serial (RS232 and RS485) devices are controlled by means of custom made embedded controllers (PSI Serial Boxes) based on the Virtex-4 FPGA chips. Such controllers run EPICS on top of Linux. The data communication is provided by the Stream Device support package [9]. Recently, commercial Moxa [10] serial data acquisition computers were integrated into the PSI controls and became a good alternative to Serial Boxes.

Another embedded solution built around Virtex-4 FPGA is a PSI controller called a "Data Concentrator", which is used to operate SITF magnet power supplies remotely via fiber optics links. EPICS talks with Data Concentrators over the controls network.

The access to GPIB instruments is done via Agilent LAN/GPIB gateways. Control software is based on the Stream Device support and communicates with those gateways using the ONC RPC protocol.

Temperature and humidity measurements are performed by dedicated sensors interfaced to EPICS via the MIDAS Slow Control Bus (MSCB) with embedded controllers [11]. The MSCB solution has several advantages over VME based systems including smaller sizes of control units, shorter cables between sensors and control units, and a bigger variety of supported sensors. System deficiencies are associated with its relatively complex setup and some operation stability issues, which might not be acceptable for the SwissFEL project.

The application development environment at PSI is built around a powerful hardware inventory database [12] together with application building and installation frameworks, which heavily rely on this database. The hardware inventory database contains the information about IOC types, their operating systems, and controls hardware components handled by them. A specially developed dynamic compiling and building script fully automates the application building process. All that has to be done by a developer is to reference this script in a project make file.

The control system configuration data and software are installed in a separate directory located on a dedicated NFS file server. All information required to run IOCs and client applications is contained there. The installation of applications on the computer network is done by means of an in-house created application installation tool, which is called swit [13]. Software revision controls is based on the concurrent version system (CVS).

In total, more than two hundred thousand control channels are setup for SITF applications. All these data can easily be configured for saving/restoring, archiving, and watching alarm conditions with the use of standard EPICS tools.

Initially, for SITF operations, synoptic displays were developed in the frames of the worldwide used EPICS MEDM toolbox. Recently, a new powerful graphical user interface (GUI) design package caQtDM [14] was created at PSI and immediately became a primary control GUI development tool for operations. The package is based on the well known Qt framework. It not only significantly expands valuable MEDM features but also makes it possible to incorporate existing MEDM screens with the use of a provided GUI converting script. As a result, switching from MEDM to caQtDM synoptic displays for SITF applications is relatively easy.

Clear PSI style guides provided by the control team for application developers help SITF operations to make sure that all applications have a consistent behaviour, which is especially important for integrating control room applications into EPICS.

SITF physics applications are written in MATLAB by machine physicists. The controls team supports this by providing and maintaining the MATLAB interface to EPICS. Physics process variables (PVs) are implemented as soft EPICS channels (i.e. channels not connected to any hardware device) holding the information relevant for

ISBN 978-3-95450-139-7

physics studies. For instance, the beam emittance measurement is time-consuming and invasive, but its result is needed as a PV for other applications and status displays.

SITF control projects are carefully planned with the use of a well-known project management tool JIRA [15], which helps one to concentrate all available resources on the most important tasks for any particular time frame.

PERSPECTIVE CONTROL DEVELOPMENTS

SITF operational performances show that its control system is adequate to the tasks associated with the facility operational goals. At the same time, the overall SITF controls experience indicates that for the future SwissFEL project new advanced control solutions are required.

Our high expectations are associated with a new IOC, IFC_1210, developed by the PSI controls team in collaboration with IOxOS Technologies SA, Switzerland [16]. IFC_1210 is a highly configurable FPGA platform associated with XMC, PMC, and FMC mezzanine slots for custom expansions, a very powerful dual core PowerPC and real time OS. It is built around a high-performance switched PCI Express GEN2 architecture. The VME support firmware implements a complete VME master/slave interface. A comprehensive FPGA design toolkit TOSCA II is available for creating various custom applications. The PSI controls team plans to gradually switch to IFC_1210 IOCs that will make much more computing power, a higher data throughput, and very flexible I/O features available for software developers. At the moment, low level RF and magnet power supply controls are already implemented on this platform. In the list are several other controls projects including the mentioned above beam-synchronous data acquisition and a generic fast ADC (including gated) support.

A thorough evaluation of compact, modular, and cost efficient WAGO I/O products [17] was very convincing to consider them as primary solutions for slow controls including temperature and humidity monitoring as well as small motor control applications.

Besides of all mentioned above, PSI plays a leading role in a new international project, which is known as EPICS version 4 (EPICS4) and which is going to become a basic toolkit for writing scientific applications at large experiment facilities in the near future [18].

CONCLUSION

SITF gives us a unique opportunity to develop and evaluate new ideas in view of the future SwissFEL. It also helps us to understand how to make our work on the control system most efficient.

Very successful SITF operations clearly demonstrate that its control system developments are in a good shape to provide all necessary control tools for the future SwissFEL component tests, commissioning, and runs.

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ISBN 978-3-95450-139-7