DIAGNOSTICS TEST STAND SETUP AT PSI AND ITS CONTROLS IN LIGHT OF THE FUTURE SwissFEL

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Abstract

In order to provide high quality electron beams, the future SwissFEL machine needs very precise beam diagnostics tools. At the Paul Scherrer Institute (PSI), the development of such tools required setting up a dedicated automated test stand, which could significantly simplify the development process. The test stand is equipped with not only major SwissFEL beam diagnostics elements (cameras, beam loss monitors, wire scanners, etc.) but also their controls and data processing hardware and software. The paper describes diagnostics test stand controls software components designed in view of the future SwissFEL operational requirements.

INTRODUCTION

The future SwissFEL facility [1] at the Paul Scherrer Institute (PSI) will produce superb photon beams for a variety of cutting-edge user experiments. The project aims to use the lowest electron beam energy compatible with 1 Å facility operation. In these conditions, to ensure successful facility lasing, the machine must be equipped with advanced diagnostics and controls tools continuously monitoring electron beam generation, transport, and compression. The SwissFEL Injector Test Facility (SITF), which has been a major platform for designing and testing such tools since for the last few years, is going to be put out of operations by the end of 2014. After that, there will be no similar platform available on site for the SwissFEL machine component prototyping and testing. In order to supply a satisfactory workbench for electron beam diagnostics and control developments, a dedicated automated Diagnostics and Controls Test Stand (DCTS) was set up in the SwissFEL diagnostics laboratory located in the SITF building. There are several advantages of this location. For instance, being in the area of a well-established SITF control system infrastructure, any required DCTS computer network is easily configurable and supportable. Another important advantage is the direct access to modern laboratory tools for efficient equipment checking and tuning.

To ensure the reproducibility of test results in the real machine environment, diagnostics and controls projects on the stand are required to organize as close to their SwissFEL operational conditions as possible. For example, wire scanner moving components must be kept in vacuum, motor steering cables have to be about 20-30 meters long, etc.

All DCTS control system software developments must be compatible with EPICS [2], which is the principal controls tool at PSI.

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DCTS DEVELOPMENTS

From its very beginning, the DCTS project was divided into several stages based on the SwissFEL type control system hardware and software availability for beam diagnostics applications.

On stage one, which was the initial step, the basic test stand control infrastructure was set up and the development of the test procedures for all tasks implemented on the test stand began.

Basic DCTS Control Infrastructure

The main DCTS control network is a general purpose 1 Gbit class C subnet. The operator console is a Linux PC furnished with a high resolution monitor. A standard SwissFEL electronics rack houses the DCTS control equipment, which includes one motion control unit and several VME64x crates.

One VME crate, which is a primary DCTS software development crate, is equipped with a new PSI control computer (IOC), IFC_1210, designed in collaboration with IOxOS Technologies SA, Switzerland [2]. The IFC_1210 is a highly configurable FPGA platform associated with XMC, PMC, and FMC mezzanine slots for custom expansions, a powerful dual core PowerPC, and a real time OS. It is built around a high-performance switched PCI Express GEN2 architecture. The VME support firmware provides a complete VME master/slave interface. Compared to the SITF workhorse MVME-5100 single board CPU, this new IOC type offers much more computing power, a higher data throughput, and very flexible I/O features available for software developers. However, to make IFC_1210 fully operational, a lot of work must be done to design and implement EPICS device/driver support software for a variety of controls hardware components that can be handled by this IOC. It was obvious to begin with the easiest part of this work, which is porting existing PSI VxWorks-specific VME memory access software to the new IOC platform. As a result, the most critical VME drivers, including the General Purpose Memory Mapping (GPMM), became available for IFC_1210 by the time of the initial DCTS setup. This has allowed one to relatively easily integrate a variety of VME control cards into the test stand controls environment and to concentrate major software development efforts on supporting fast, not less than 250 Mega-Samples-Per-Second (MSPS), 16 bit ADC, high speed DAC, and digital IO FMC modules available from IOxOS Technologies SA.

The test stand timing system is realized in the second VME crate. It will provide control device triggering mechanisms and synchronous transmissions of DCTS

critical data. The timing system is based on the latest generation of global event distribution products from Micro-Research Finland Oy. Its core equipment is an EVent Generator (EVG) VME card, which is configured to transfer some key real-time system parameters in parallel with the event distribution. One such parameter is a 64 bit integer number, which is implemented as a simple counter incrementing at a rate of 100 Hz. This number simulates a SwissFEL bunch ID, which will be assigned to each electron bunch produced in this facility and used to mark all vital machine and experimental data with a unique tag. Such data tagging (or data stamping) is essential for SwissFEL machine physics and experimental research programs and is called Beam Synchronous Data Acquisition (BSDAC) [3]. All required timing information for DCTS users is provided by VME and PCI EVent Receiver (EVR) modules talking to the EVG card.

The content of the VME crate number three is planned to be flexible, depending on current DCTS needs. Initially, this crate was equipped with an MVME-5100 IOC running the VxWorks OS, an EVR card, and a Generic PSI ADC Carrier (GPAC) board [4]. This configuration has proven its excellent performance in digitizing high frequency (up to 250 MHz) analogue signals. That is why it is very helpful as a reference system in the development/tuning of the control software handling fast ADC IOxOS modules.

The DCTS motion control unit is a Power Brick LV-IMS controller from the Delta Tau Data Systems Inc. The unit can handle up to 8 stepper motors together with their encoders. In its standard configuration, the Power Brick LV-IMS runs EPICS on top of a Linux OS with a real time kernel, which makes it especially attractive for SwissFEL applications. For instance, in a combination with an EVR card, it can become a part of a BSDAC system.

The DCTS application development environment follows PSI standards [5]. It is based on a powerful hardware inventory database, very efficient application building and installation frameworks, in-house created application installation tools, and the concurrent version system (CVS) dependent software revision control.

The work on the DCTS project is organized around a dedicated TWiki page, a popular project management tool JIRA, and a PSI Electronic Logbook (ELOG) [6]. This allows one to efficiently concentrate all available resources on the most important tasks for any particular time frame.

DCTS User Application Setup Test Procedures

Any facility control system serves its users. In the frames of the DCTS control system, each user project (e.g. a wire scanner) is represented as its adequate user application setup (see Fig. 1).

Users employ a set of instruments to provide the required operational conditions and to monitor the state of the project. Instruments are supplied with their control interface equipment, allowing one to operate these instruments efficiently, including remotely. For example,

a combination of a stepper motor and its encoder allows one to rotate a mirror and to measure the rotation angle. The facility control system accesses the control interface equipment via the control system hardware. The PSI control team supports a wide variety of control hardware types, which cover all major control interface and data communication standards utilized in research institutions worldwide. These hardware types form the PSI standard control system hardware. The lists of standard control system hardware types and control interface equipment compliant with these types are published in official PSI control documents. The main requirement to any user instrument to be included into the PSI control system is that its control interface equipment must be listed in those documents. For example, a stepper motor and its encoder must be PSI standard. We note that such control hardware standardization allows a relatively small PSI control team not only to support numerous control system users at PSI but also to do a lot of development work, which, in particular, makes the mentioned above lists constantly expandable. The DCTS control system software, which manages instrument operational functions based on the control hardware, forms a user instrument control support package.
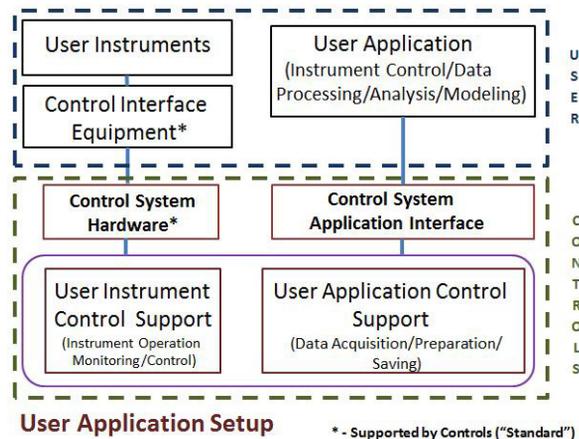

Figure 1: DCTS user application setup overview.

As a rule, users operate their instruments remotely, from applications running on computers connected to the control network. The applications (e.g. MATLAB programs, Perl scripts, etc.) talk to the control system on the basis of the control system application interface, such as the EPICS Channel Access (CA). In most cases, they also perform lots of calculations based on instrument data analysis and processing models. For example, it can be beam position and transverse size calculations with the use of the beam image on a fluorescent screen obtained from a camera looking at that screen.

Some data preparation work for DCTS user applications is done directly on the IOC by a dedicated software module. For example, bunch ID tagged data are collected in allocated EPICS waveform records. Such a software module and the IOC software taking care of the control system application interface form a user application control support package.

Based on the above definition, DCTS user application setup test procedures are divided into the next three categories: user instrument control support, user application control support, and user application test procedures.

The user instrument control support test procedures must be developed by the control system specialists. In particular, such procedures have to include the detailed instructions of how to

- set up and test the user control interface equipment,
- connect this equipment to the control system,
- run the instrument control software and make sure that it communicates with the interface equipment properly,
- troubleshoot any possible control system hardware and user instrument problems.

As a rule, this is done by providing detailed instrument control setup/test/troubleshoot documentation and related project operational tools (e.g. graphical user interface panels).

The user application control support test procedures have to be defined by both control system specialists and users. The goal is to make sure that any required data preparation for user applications is done correctly.

Finally, the user application test procedures must be developed by control system users. The procedures have to demonstrate that applications properly control user instrument operations and their data processing software works correctly, which requires the design and use of instrument signal sources with well-known properties, such as a round laser beam as the camera image source.

One of the main goals of the DCTS is to develop all user project specific test procedures based on the experience gained on the test stand.

Wire Scanner Application Setup

After setting up its basic control infrastructure, the DCTS project advanced to its stage two, which was the SwissFEL type wire scanner (WS) application setup.

The basic idea of a WS is simple. Thin (tungsten, carbon, etc.) wires stretched between two prongs of a metallic fork move through the beam. Secondary particles produced by the beam intercepting a wire are registered by a beam loss monitor (BLM) detector, which is usually a combination of a scintillator and a photo multiplier tube (PMT). The beam profile is completely defined by the level of the BLM signal as a function of the corresponding position of the wire.

The SwissFEL WS control interface equipment consists of a stepper motor with its position encoder and an in-house developed PMT control box. The stepper motor moves the WS fork. The output voltage of the PMT control box is proportional to the PMT signal level. All WS data must be bunch ID tagged.

The associated DCTS WS control hardware includes a DeltaTau stepper motor/encoder controller and an ADC control module. The electron beam is simulated by a laser beam.

In its initial configuration, the WS was set up on the test stand without bunch ID tagging means. Nevertheless, its operations contributed to a basis for WS project test procedures.

In particular, the WS application test procedures include the next steps to be implemented:

- move the WS fork through the laser beam,
- detect scattered photons detected by the loss monitor PMT and corresponding wire coordinates,
- calculate the laser beam size and compare this result with the diameter of the used laser beam.

Nearest DCTS Plans

A series of electron beam diagnostics and control projects is in the list to work on at the test stand in the next few months. The WS data bunch ID tagging has to be implemented. The SwissFEL camera server and camera image saving system must be configured to operate at 100 Hz. A productive IOxOS fast ADC control software development environment has to be created. Besides, as always, all this must be accompanied by the work on the proper project test procedures.

CONCLUSIONS

The DCTS project gives SwissFEL control system users and specialists a unique opportunity to efficiently work on their projects during the SwissFEL construction. A high flexibility of the DCTS framework allows one not only to create and test project components but also to simplify the development of powerful tools, which can be used to make sure that these components are fully operational: instrument and control hardware test signal sources, project test procedures, project setup and operation plans, etc.

ACKNOWLEDGEMENTS

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