COMMISSIONING OF THE NEW PRE-ACCELERATOR CONTROL SYSTEM AT DESY

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Abstract

In the course of the PETRA 3 project, the control systems of the pre-accelerators at DESY have been rebuilt. At all levels from front-end electronics via server or client applications to networks, radical and significant changes have been introduced. This paper describes the chosen architecture and technologies, and reports the experiences gained so far.

INTRODUCTION

After having switched off the proton-lepton collider HERA 2, the booster PETRA 2 is currently being transformed into the high-brilliance 3rd-generation light source PETRA 3 [1]. The design values for the new storage ring are 6 GeV for the particle energy and 100 mA for the current. The transverse particle beam emittance is expected to be 1 nmrad. Fourteen undulator beam lines operated by HASYLAB (Hamburger Synchrotron-strahlungslabor), EMBL (European Molecular Biology Laboratory) and the GKSS research centre will provide photons for various experiments (X-ray diffraction and imaging, high-energy resolution spectroscopy, material science, X-ray absorption and resonant scattering as well as structural biology).

Within the scope of the PETRA 3 project, the accelerator control systems and fractions of the front-end electronics of the electron/positron pre-accelerators LINAC and DESY 2 have been upgraded. The new systems are based on the TINE [2] control system suite. This effort was an important milestone and successful proof-of-principle of most of the technologies intended to be used also for the new control system of PETRA 3. The commissioning of LINAC 2 and DESY 2 has been finished with the successful and stable delivery of positron beam to the light source DORIS, still be in operation at DESY. User beam operation at PETRA 3 is expected to start not before January 2009.

FRONT-END ELECTRONICS AND DEVICE INTERFACES

The upgrade of the front-end electronics is a particular challenge of the project. Fractions of the old existing DESY-proprietary legacy SEDAC field-bus network and the attached electronics have to be preserved, while hundreds of magnet or kicker power supply and vacuum controllers will be exchanged by modules based on CANopen industrial field-bus technology. In addition, the modern TwinCAT [3] soft Programmable Logic Controllers are becoming increasingly popular. Off-the-shelf electronics for beam diagnostics, signal digitizing and video capturing have to be integrated seamlessly.

CANopen-based Front-End Electronics

New developments concentrate on CANopen as field-bus interface standard. We have established a hardware standard using industrial 3U-Euro crates with general purpose electronic boards which we have developed based on the Coldfire and HCS12 microcontroller [4] families. The corresponding Vector [5] CANopen implementations have been adapted to our needs. In order to communicate with the CANopen stack the developer of the application software registers the user specific variables in the CANopen object dictionary and provides the user specific code for a predefined set of call-back functions.

To improve flexibility and to ensure pin compatibility with the device hardware not being replaced, the general purpose processor boards are connected with user-specific boards implementing the corresponding electrical and mechanical interfaces. The cables to the user-specific equipment are connected at the back of the crate.

The outdated SEDAC-based controller modules of the power supply control electronics have been replaced by CANopen-based controllers. The front-end electronics to control the pulsed kicker and septa magnets consisting of five different modules has been replaced completely by novel controllers. This exchange includes also the timing modules which distribute the necessary trigger signals among the components and diagnostic devices of the pre-accelerators and corresponding beam transfer lines. Ten percent out of about 1500 controllers to be finally installed within the scope of the PETRA 3 project is now in place and successfully commissioned in the field.

The CANopen bus lines are connected to PC104-like systems running embedded Linux and acting as control system device servers and as CANopen bus masters. Most of the systems installed are working properly, but not all issues concerning long-time stability could be addressed and solved satisfactory due to lack of commissioning time.

Front-End Device Access with the Common Device Interface

The Common Device Interface CDI [6] has been developed to provide both a common interface to various front-end electronic standards and an interface to the accelerator control system (Fig. 1). It offers bus plugs for CANopen, SEDAC, RS232, Siemens SIMATIC PCS7/Ethernet and Beckhoff TwinCAT ADS.

The devices attached to the corresponding buses are registered using entries in the CDI database. The user specifies the name of the entry, the bus type and address parameters, the data access rule (READ, WRITE, atomic WRITEREAD, …) and format (short, long, text, …) as well as data manipulation parameters (mask, pattern, limit, calibration rule).

Devices of the same type can be described by template entries. Additional coding by the user is not required. On initialization, the CDI starts a TINE control system server which exports to the control system the device properties described in the CDI database.

CDI-based servers have demonstrated their capability to interface flexibly the Ethernet- and the fieldbus-dominated control system domains. Complex use cases such as the repetitive read-out of the beam position monitors at DESY 2 with 6¼ Hz could be realized successfully. Hundreds of status and alarm values of the LINAC 2 RF system are efficiently monitored and distributed. Stepping motor systems based on TwinCat technology have been integrated with minor effort.

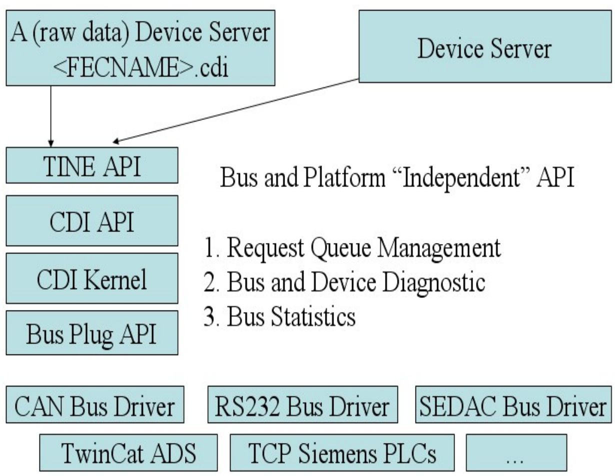

Figure 1: Architecture of the Common Device Interface

APPLICATION DEVELOPMENT

Application development is a major and important task within the control system upgrade project. Device and middle-layer servers are implemented in C/C++, Java, VisualBasic and LabView. The control room client applications for the accelerator operators, equipment experts, and scientists are implemented as rich client applications with Java, LabView and Matlab or as browser-based thin client applications using HTML and JavaScript.

Java Applications Dedicated for Device Control, Diagnostics and Accelerator Operation

According to our experience, control room applications based on the rich-client model are best suited for providing optimum visualization and performance. Examples for rich client applications are complex orbit displays which might combine position monitor readings and orbit correction tools or archive data viewer with the option to correlate different data channels in various contexts.

Framework classes for client and server [7] applications have been developed to ensure design conformity and to handle initialization data. To facilitate coding, the ACOP (Accelerator Component Oriented Programming) toolbox [8] is used for simple data access and rendition. ACOP components are Swing components following the Java beans standard. Besides ACOP chart, a slider, a wheel switch, a dial knob, an animated label, a gauge and a video component have been implemented. All ACOP components support design- and runtime customization such as adding a channel to a chart or dragging and dropping channel metadata to another application instance.

Various Java server and client applications for device control and accelerator operation have been implemented and commissioned in close contact with the control room operators and accelerator coordinators. Laymen and expert views and web links to help documents are integral functionalities of each application. The status of all permanent client-to-server connections of an application is routinely supervised and link errors are notified to the operators. For example, Fig. 2 shows the complex control room panel to operate LINAC 2 summarizing all relevant information and actions for the operators. Other applications include live video image streams from optical diagnostic devices.

A high value has been set on diagnostics applications and tools to automate accelerator operation. All measured signals from bunch current monitors, pulsed RF devices and injection or ejection components etc. are digitized at the front-end level and available as scope-like traces through the control system. The capability of the control system to generate, distribute and visualize read-back values with a repetition rate of 6¼ Hz synchronously with the DESY 2 accelerator cycle has been successfully proven.

The so-called file catalogue browser and sequencer applications are the common save-and-restore tools. Based on XML-like templates, the catalogue browser contains data sheets of set values to be loaded into the front-end devices and of events triggering some actions of accelerator components. Various check and filter methods and routines to compare different accelerator states or to detect differences between set and read-back values etc. are provided. The sequencer application combines different data sheets into sequences which are also defined by XML-like data structures. The progress and success of each step of a sequence is continuously monitored and notified to the operators. The sequencer provides a control system API to issue actions by the sequencer such as switching of all magnets in a predefined procedure. Finally, the sequencer application defines the current machine state which is broadcasted within the controls network. Work is still ongoing to combine set values of corrector magnets and orbit data within the save-and-restore tool as reference values for the operators which have to be reproduced for optimal performance.

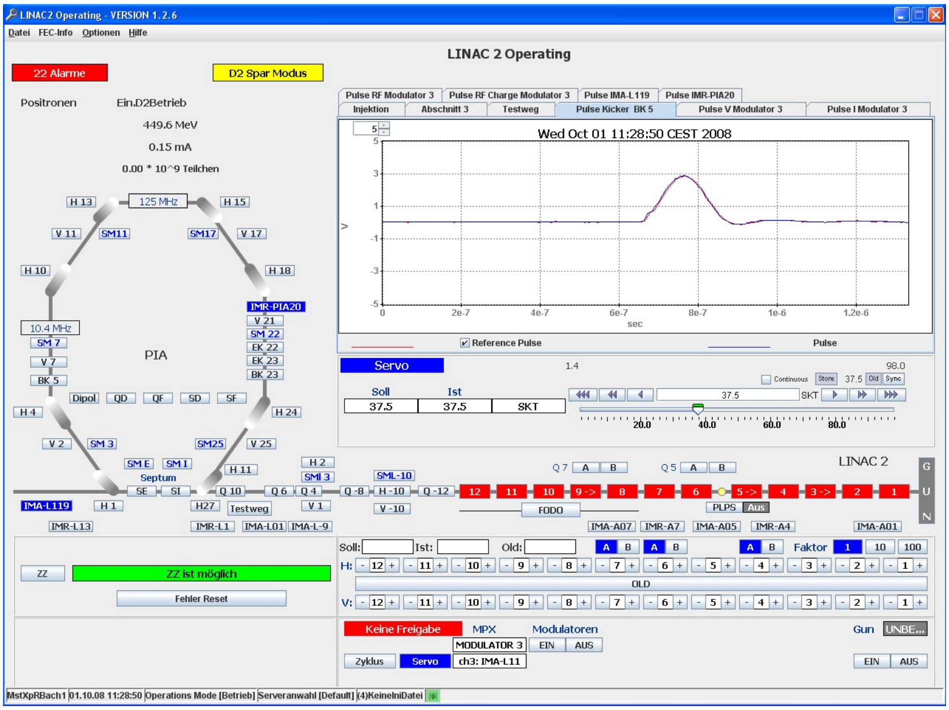

Figure 2: Java main operation panel for LINAC2

Generic Java Applications

A set of generic Java application have been implemented on contract basis by Cosylab [9]. An alarm viewer panel informs the operator about critical device states. All alarms are processed and archived by the central alarm system which is an associated service of the TINE control system. The alarms are sorted by various categories and rated according to a predefined alarm severity scheme. Open as well as already closed alarm tickets can be displayed simultaneously if requested. Detailed metadata complete the pure alarm data. Similarly, the different archive viewer applications support quick on- and off-line analysis of all types of archived accelerator parameters. Charts for data sets arranged as time series or event-driven data structures and correlation plots are provided. The so-called scope trace viewer is a configurable graphical interface application with scope-like look-and feel to all data traces available through the control system. In addition, an operation statistics application and various applications for administrative purposes complete the set of applications delivered.

OUTLOOK TO PETRA 3

The successful commissioning of the control systems of LINAC2 and DESY2 was an important milestone and successful proof-of-principle of most of the technologies intended to be used also for the new control system of PETRA 3. All front-end controllers have been fabricated and will be installed following the progress of civil construction and providing basic infrastructure. While many control room or server applications and all control system services such as alarm system or archive systems will be cloned, slightly modified or re-configured, applications dedicated to orbit measurement, orbit correction, orbit feedback and accelerator protection have to be implemented from scratch on. Data connections between the accelerator control system and the photon beam line devices have to be established and advanced diagnostic systems have to be integrated and controlled.

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