THE CONCEPTUAL DESIGN OF THE CONTROL SYSTEM FOR THE FUTUTRE LOW-EMITTANCE LIGHT SOURCE PETRA III AT DESY

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Abstract

At DESY, the accelerator PETRA II, predominantly used as booster for the proton / electron collider HERA, will be transformed into a 3rd-generation light source (PETRA III) after the final shutdown of HERA operation mid 2007. In addition, the existing technical systems of the electron or positron pre-accelerators LINAC II and DESY II will be improved to fulfil the stringent requirements of the future PETRA III operation modes such as top-up injection. Within this effort, the control system will be upgraded to serve beam operation for a further 10 years. The anticipated changes aim (1) to reduce the dependency on specific computer platforms, (2) to establish the TINE (Threefold Integrated Network Environment) software suite for remote control of all accelerators involved, (3) to standardize and modernize the front-end controllers and interfaces, (4) to reduce the future maintenance and development effort, and (6) to fulfil the state-of-the-art safety requirements for an open control system. In this paper, the conceptual design of the control system that has been recently developed will be presented.

INTRODUCTION

For more than two years, DESY has been changing its scientific profile from a predominantly high-energy physics laboratory to a unique synchrotron light research centre. This change has been manifest in by several decisions, namely (1) to switch off the proton-lepton collider HERA II and to transform its booster PETRA II into a synchrotron light source (PETRA III), (2) to upgrade the former Tesla Test Facility (TTF) into a user facility (VUVFEL), and (3) to participate in the project of a linear-accelerator-driven hard X-ray free electron laser (XFEL) located at the DESY site which is presently being negotiated between several European partner states. In addition to these facilities, DESY also operates the 2nd-generation synchrotron light source DORIS III.

The future facility PETRA III will be a high-brilliance 3rd-generation light source [1]. The design values for the new storage ring will be 6 GeV for the particle energy and 100 mA for the current. The transverse particle beam emittance ist expected to be 1 nmrad. More than ten undulator beam lines operated by HASYLAB (Hamburger Synchrotronstrahlungslabor) 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).

At the end of July 2007, operation of HERA II will be terminated and all other proton facilities at DESY will be shut down. In the following year, PETRA II will be upgraded while the electron or positron pre-accelerators LINAC II and DESY II continue supplying DORIS III with particles. Beginning 2008 the pre-accelerators will interrupt service for 6 months, as the re-commissioning of LINAC II and DESY II is scheduled for summer 2008 and the initial commissioning of PETRA II for autumn 2008. User beam operation is expected to start in January 2009.

CHALLENGES FOR ACCELERATOR CONTROLS

The novel operation mode of PETRA III as a continuously running high-quality light source with low down time places strict requirements on the availability, stability and performance of the control system architecture, tools, hardware components and application programmes of PETRA III and the associated pre-accelerators LINAC II and DESY II. Since stable operation of HERA II and DORIS III has to be ensured until mid or end 2007, respectively, the upgrade schedule in 2007/2008 is very tight. A reasonable balance between continued use of proven technologies and upgrades using new technologies and ideas has to be found.

The front-end electronics of PETRA II, LINAC II and DESY II are in part older than 25 years and mainly designed according to proprietary DESY standards. In order to follow the technological developments a substantial exchange of front-end hardware is mandatory. Similarly, the control systems were adapted several times to additional user requirements and technological changes such as the advent of the personal computer (PC). As a consequence, maintenance of the corresponding control systems is very resource consuming and a re-adjustment or even a re-design of architecture, services and infrastructure is strongly recommended.

The challenges of an almost simultaneous upgrade of the control systems and the front-end electronics of PETRA II, LINAC II and DESY II can be mastered by our long-term experience with (1) a modular, distributed and multi-layered control system architecture and (2) the operation and administration of a complex control system infrastructure consisting of more than 400 computers connected via Ethernet.

CONTROL SYSTEM ARCHITECTURE

The proposed system uses a multi-layer architecture linked by the integrating middleware or software bus TINE (Threefold Integrated Network Environment), a set of communication protocols and services developed over the past years as the core of the HERA I/II control system [2]. TINE is now in a mature state. Figure 1 illustrates the proposed architecture.

Software Bus

TINE is a multi-platform system, running on such legacy systems as MS-DOS, Win16, and Vax VMS as well as Win32, Linux, most Unix machines, VxWorks and NIOS. TINE is also a multi-protocol system to the extent that IP and IPX are both supported as data exchange protocols. Finally, TINE is a multi-control system architecture system, allowing client-server, publisher-subscriber, broadcast and multicast data exchange.

TINE provides application programmer interfaces (APIs) for Java, VisualBasic, C/C++, LabView, MatLab and scripting tools. An interface for the laboratory automation environment AgilentVee (formerly HPVee) will be prepared.

The TINE client/server implementation in C is widely used while the corresponding JAVA implementation is presently being brought to fruition [3].

Name services are provided with plug-and-play automated server registration.

Besides user access control, TINE offers a repeater and redirection mechanisms. The repeater mechanism is suitable for relieving delicate servers such as orbit feedback servers of undue communication burden or data archiving duties. Redirection allows for instance redirecting of locally registered devices (or even ‘local’ hardware access) to a remote server.

TINE includes interfaces to several associated services. Data filtering and archiving, event handling, alarm filtering and archiving are already supported. Interfaces for central message processing and archiving as well as to the common accelerator component database will be developed.

Access to the photon beam line equipment of HASYLAB will be performed directly via the TINE protocol and APIs. An EPICS-to-TINE translator [4], routinely used to access process data of the HERA Helium refrigerator plant, will be used to integrate seamlessly EPICS IOCs controlling mains power, water-cooling and ventilation facilities. In addition, the implementation of TINE as an UDDI-based Web service with a TINE-to-SOAP proxy interface is currently under consideration.

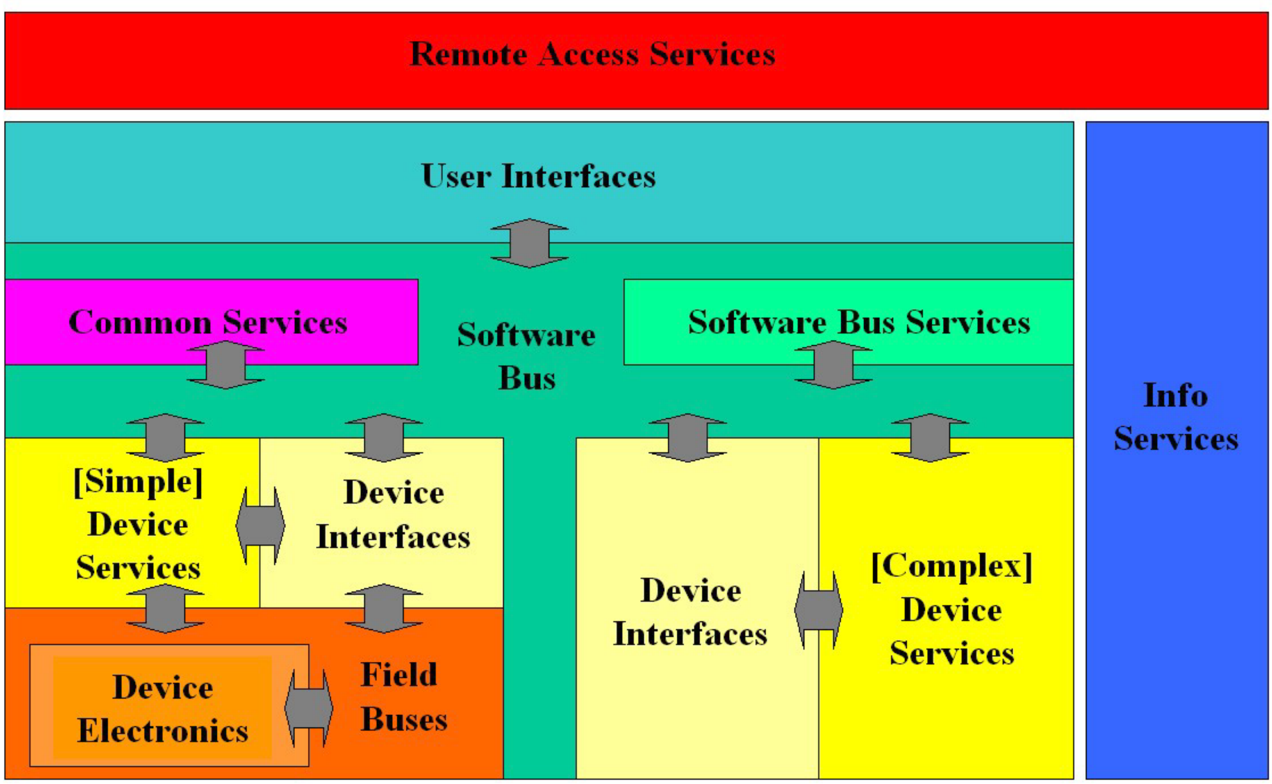

Figure 1: Proposed Control System Architecture.

User Interfaces

According to our experience, control room applications based on the thick-client model are best suited for providing optimum visualization and performance. For instance, the integrated operation of LINAC 2 and DESY 2 in conjunction with the complex synchronisation controls requires very specific operator display and operating features.

To ensure platform independence, Java is preferred and recommended as the programming language even for graphical applications. The ACOP (Accelerator Component Oriented Programming) toolbox [5] offers a powerful graphical user interface for simple data access and rendition. Application programmer interfaces also exist for MatLab and scripting tools to encourage accelerator physicists to develop complex tuning and measurement algorithms.

Templates for standard applications are currently being prepared to ensure design conformity and reuse of general software classes.

Complex Device Services and Common Services

Many users of the control system will use common services such as data archiving, event processing and alarm handling or central logging. Most of these services have been already developed and successfully implemented at HERA and require only minor modifications.

Complex device services are server applications with system-wide responsibilities. Examples are (1) feedback loops combining beam orbit data, beam optics algorithms and magnet current settings, (2) applications representing complete RF systems with many different components and dependencies or (3) process automation and supervisor tasks interfering with various technical sub-systems and components.

Both, common device services and complex device services will in general not have direct local access to fieldbus interfaces or device electronics. We propose to use rack-mounted Linux or Windows PCs running with a restricted, well-configured set of system services for safety and reliability reasons. Application programmer interfaces will be provided for Java, VisualBasic and C/C++. A graphical wizard tool helps to generate code skeletons already fully operational and integrated into the control system to increase programming efficiency and conformity.

Simple Device Services and Field Buses

Simple device services are sufficient for a fraction of the technical subsystems, including single devices such as digital oscilloscopes or electronic modules providing a few ADC channels, only.

We plan to use rack-mounted, crate-hosted (cPCI, VME) or embedded (PC104) CPUs to ensure reliable operation even in non-office environments. Similar to the complex device services, a wide set of APIs including laboratory automation environment such as LabView will be offered to allow choice of the programming language that is best suited for the control task to be done. Obviously, in the case of a VME CPU running VXWorks or an embedded PC104 system running Linux only the C API can be used.

In general, these systems are directly connected to a fieldbus or another low-bandwidth data link. A common device API [6], which runs as a separate TINE equipment module, is presently being developed to offer a generic access to the device electronics attached to those links. Plugs will be available for CANopen, the DESY-proprietary field bus SEDAC, GPIB, RS232, Profibus and USB, as well as VME.

Specific stand-alone and off-the-shelf test and measurement instruments such as oscilloscopes or spectrum analysers do not in general fit seamlessly into control system architectures. Proper instrument integration often imposes an undue burden on the application developer. To simplify this task, we propose to use IVI-foundation compliant instrument drivers. The Interchangeable Virtual Instrument (IVI) standard defines interfaces to generic virtual instrument drivers in order to avoid vendor-specific incompatibilities.

Device Electronics

A commonly used front-end hardware standard is mandatory to ensure efficient long-term maintenance of hardware and software. At DESY, hardware standardization was enforced by the DESY-proprietary fieldbus standard SEDAC with decreasing success during the last years. SEDAC is now more than 25 years old and is experiencing strong competition from modern industrial fieldbuses or data links. We plan to establish a new standard for DESY based on the industrial Euro-crate standard and the industrial fieldbus standard CANopen to regain the necessary flexibility. An embedded PC104 system, which runs Linux and which is attached to the CAN line, will parse the fieldbus data to the software bus and vice versa.

Design work for generic electronic boards based on three different processor types (Motorola 68HS12, Motorola Coldfire, Altera NIOS II) has been initiated. Customer-specific mezzanine boards will implement the user interfaces and customer-specific connector boards will provide the input-output plugs for the signal cabling.

Web-based Information Services

The storage ring operation will be supported by several Web-based information services. An instance of the electronic logbook, originally developed to document the TTF operation [7], will be customized for PETRA III. A chat or dialog tool will provide communication between accelerator operators and beam line physicists. Overview charts and a portal to access system and component documents will support the off-line work.

Remote Access Services

According to the ideas of a Global Accelerator Network (GAN) [8] all accelerator equipment should be designed to allow remote control and remote maintenance. Within this context, secure access to the control system is an important issue. We plan to install a network firewall to separate the control systems of PETRA III, LINAC II and DESY II from the DESY intranet and the worldwide Internet. Access via (1) terminal services and (2) a VPN (Virtual Private Network) proxy server will ensure the integrity of the control systems and the associated services.

SUMMARY

Within the scope of the PETRA III project at DESY, the control systems and the front-end electronics of PETRA II and the pre-accelerators LINAC II and DESY II will be upgraded. The expected strict requirements on the availability, stability and performance of the PETRA III operation suggest a substantial exchange of front-end electronics and a major re-design of the control systems involved. A reasonable balance between continued use of proven technologies and upgrades using new technologies and ideas has to be found. PETRA III will start user beam operation in January 2009.

Key elements of the proposed conceptual design are (1) TINE as integrating software bus to provide efficient data communication mechanisms and support services, (2) control room applications based on the thick-client model for optimum visualization and performance and Java as programming language to ensure platform independence, (3) server-side control system APIs in various languages to allow choice of the language that is best suited for the control task to be done, (4) a common device interface for generic access to various fieldbuses, and (5) CANopen as the future DESY interface standard for device electronics to ensure efficient long-term maintenance.

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