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THE DO's AND DON'Ts IN PROCESS CONTROLS LESSONS LEARNED OVER 35 YEARS

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Abstract

Designing, implementing and maintaining process control systems for cryogenic plants requires different viewpoints compared with those in machine controls. 24/7 operations for more than a year is a basic requirement. Hardware and software must be designed to fulfil this requirement. Many projects are carried out with industrial partners. Companies specify the process control logic which gets implemented by the local DESY team. Responsibilities, time tables and milestones must be clearly defined in such a case. Several cryogenic installations have been equipped with state of the art process control systems for cryogenic controls. Where the last one being the European XFEL. In the course of time commercial and open source systems were implemented and maintained. Control loops were basically always implemented in front end controllers running the real-time operating system VxWorks and EPICS as the control system toolkit. The approach to use PLCs will be discussed as an alternative approach. Large installations like the European XFEL require good project planning. Our success story will finalize our look back and initiate our look forward.

PROCESS CONTROLS AT DESY

In 1982 process controls for cryogenic systems was implemented in hardware PID controllers. Only a few engineers had the knowledge how to operate such a system. A failure over night was a night mare because no diagnostics were installed.

Over the years archive systems were installed. Even alarm systems found their way into cryogenic control systems because 24/7 operations required immediate action if some conditions were suspicious.

Over the years all of the cryogenic processes (cryogenic plants and cryogenic distribution systems) are controlled by process controllers. Some of them went through two basic refurbishments. In the end all cryogenic process controls at DESY and the XFEL are implemented in EPICS front end controllers – so called Input Output Controller (IOC).

This paper will describe a subset of the experiences we gained of the years. Namely: PLC integration; testing of new equipment and project management issues.

TO USE OR NOT TO USE PLCS IN PROCESS CONTROLS

PLCs can be really useful – there is no doubt. The question is: 'Where should PLCs be used?'

PLCs for Machine Interlocks

A very prominent usage for PLCs is the area of hardware interlocks. In former times this kind of hardware protection was implemented in hard wired logic. This logic slowly moved into intelligent controllers and finally into PLCs. These interlocks are well defined. They are thoroughly tested and should not be altered. Implementing this logic in a PLC is a no-brainer and used basically for every system in place.

PLCs as Data Concentrator

The next occasion where PLCs find their way into control systems is the usage as a data concentrator. There are a lot of different I/O signal types which can be connected via specific signal-conditioning modules to PLC type of communication controllers. Depending on the vendor theses are PLCs with I/O modules or intelligent communication controllers with I/O modules which can be programmed like a PLC.

In both cases the controller or the PLC will function as a data concentrator and will not be used for control functions in the field. Typically these controllers will be connected to a field bus like Profibus or CAN or (real-time) Ethernet.

Communication with the Process Controller

The communication between the data concentrator and the process controller will run through one of the field busses mentioned above. Therefore the process controller has to implement the necessary driver for that type of connection.

The communication must be configured for each individual I/O signal as if the signal would be connected to the process controller directly. This kind of configuration will be typically limited to one channel for each I/O signal. Basically this is a one to one representation.

Reliability

Reliability is a strong argument in favor of PLCs. For sure PLCs are known for their reliable runtime behavior. They run in thousands of instances and the code is (should be) thoroughly tested. All of the hardware components are nearly mill proof and reliable as well. Crashes of PLCs are not known to the author. If the same kind of application is run on an EPICS IOC one would have to put the same constraints on software and hardware on the EPICS implementation. A Windows or Linux operating system will hardly reach the level of reliability which a PLC based OS will provide. A 'real' real-time operating system like VxWorks is tuned for reliability and will work differently from OS's which require for instance hard

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STATUS OF THE TPS CONTROL SYSTEM

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Abstract

Control system for the Taiwan Photon Source (TPS) has been delivered in mid-2014 to support commissioning and routine operation of the accelerator system. The TPS control system adopts EPICS toolkits as its frameworks. Various subsystems interface to the control system according its specific requirements. Operation experiences accumulated during last four years confirmed the system working well. Minor revisions were made to improve the system performance. Current status of the control system and ongoing developments will be summarized in the report.

INTRODUCTION

The TPS [1] is a latest generation of high brightness synchrotron light source which is located at the National Synchrotron Radiation Research Center (NSRRC) in Taiwan. TPS consists of a 150 MeV electron linac, a booster synchrotron, a 3 GeV storage ring, and experimental beam lines. The control system environment was ready in mid-2014 to support subsystem integration test and accelerator commissioning [2]. User service of the TPS was started since 2016.

Adequate and reliable functionality of control system is one of the key to the success of TPS commissioning. Control system for the TPS is based on the EPICS framework [3]. The EPICS is based on the definition of a standard IOC structure with an extensive library of driver and support a wide variety of I/O cards. The EPICS toolkits have various functionalities which are employed to monitor and to control accelerator system such as control page creation, data archiving, alarm handling and etc.

The TPS control system consists about three hundred of EPICS IOCs. The CompactPCI (cPCI) is equipped with input/output modules to control subsystems as standard IOC. The other kinds of IOCs are also supported by the TPS control system, such as BPM IOCs, PLC IOCs, various soft-IOC and etc.

To achieve high availability of the control system, emphasis has been put on software engineering and relational database for system configurations. Data channels in the order of 10^5 will be serviced by the control system. Accessibility of all machine parameters through control system in a consistent and easy manner will contribute to the fast and successful commissioning of the machine. High reliability and availability of TPS control system with reasonable cost and performance are expected.

SYSTEM COMPONENTS

The TPS control system provide an environment for operation of the accelerator system. It integrated various subsystems together [4]. Details of some parts of control system are summarized in the following paragraph.

Control Server Environment

Various servers include file server, archiver server, database server, alarm server, boot servers, ...etc. are supported by the control system. There server support operation of the whole system.

General EIPCS IOC Interface

There are many different kinds of IOCs at equipment layer to interface various subsystems and instruments. They need meet various requirements of functionality requirements, convenience and cost consideration. Type of IOCs are summary in Table 1. Most of the devices and equipments are directly connected to cPCI IOCs with EPICS. The cPCI EPICS IOC is equipped with the cPCI-6510 CPU board. The cPCI-7452 128 bits DI/DO module is used for BI, BO solution. ADC and DAC modules in IP (Industry pack) module form-factor are used for smaller channel count application, such as insertion devices control. Event system modules are in 6U cPCI form-factor. Private Ethernet will be heavily used as field-bus to connect many devices. Power supplies of all magnets except for correctors are equipped with Ethernet to the EPICS IOC. Multi-axis motion controller with Ethernet interface is the standard for the control system.

Ethernet attached devices are connected to the EPICS IOC via private Ethernet. Devices support VXI-11, LXI, Raw ASCII and Modbus/TCP protocol are connected to EPICS IOC directly by TCP/IP interface. Devices of this category include intermediate power supply, temperature acquisition (RTD or thermocouple), digital multi-meters, oscilloscopes, signal generator, and other instruments.

All corrector power supplies are controlled by the corrector power supply controller (CPSC) module [5]. The CPSC embedded EPICS IOC, it can access via channel access protocol. The CPSC equips with 20 bits DAC and 24 bits ADC. Two SFP ports supported by the on board FPGA, these SFP ports are receive correction setting from fast orbit feedback FPGAs located at BPM platforms via AURORA protocol.

All BPM platform are embedded EPICS IOCs. Some PLC based embedded IOC were adopted for machine protection and interface of pulse power supply of pulse magnet.

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OVERVIEW AND STATUS OF THE SHINE CONTROL SYSTEM

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Abstract

The high-gain free electron lasers have given scientists hopes for new scientific discoveries in many frontier research areas. The Shanghai HIgh repetition rate XFEL aNd Extreme light facility (SHINE) was proposed by the central government of P.R. China on April 2017, which is a quasi-continuous wave hard X-ray free electron laser facility. The control system is responsible for the facility-wide device control, data acquisition, machine protection, high level database or application, as well as network and computing platform. It will be mainly based on EPICS to reach the balance between the high performance and costs of maintenance. The latest technology will be adopted for the high repetition rate data acquisition and feedback system. The details of the control system design will be reported in this paper.

OVERVIEW

Owing to the wide range of applications of X-rays in the research fields of physics, chemistry and biology, facilities with the ability to generate X-rays were developed continuously in the last century. The free electron laser (FEL) is a novel light source, producing high-brightness X-ray pulses. To achieve high-intensity and ultra-fast short wavelength radiation, several X-ray FEL facilities have been completed or under construction around the world [1].

The first hard X-ray FEL light source in China, the so-called Shanghai HIgh repetition rate XFEL aNd Extreme light facility (SHINE), is under construction. It will utilize a photocathode electron gun combined with the superconducting Linac to produce 8 GeV FEL quality electron beams with 1 MHz repetition rate.

The control system of SHINE is responsible for the facility-wide device control, data acquisition, machine protection, high level database or application, as well as network and computing platform. It will provide operators, engineers and physicists with a comprehensive and easy-to-use tool to control the machine components to produce high quality electron beam and free electron laser.

According to the experience of SSRF and SXFEL, the control system of SHINE will be mainly based on EPICS (Experimental Physics and Industrial Control System) to reach the balance between the high performance and costs of maintenance. EPICS is a set of open source software tools, libraries and applications developed collaboratively and used worldwide to create distributed soft real-time control systems for scientific instruments such as particle accelerators, telescopes and other large-scale scientific experiments.

ARCHITECTURE

As shown in Fig. 1, the control system can be divided into four layers to ensure the performance and scalability, which are operator interface layer, middle layer, device control layer and data acquisition layer.

The operator interface layer offers graphical user interface (GUI), command line interface (CLI) and high-level application programming interface (API) to operators, engineers and physicists. It allows them to interact with the machine components.

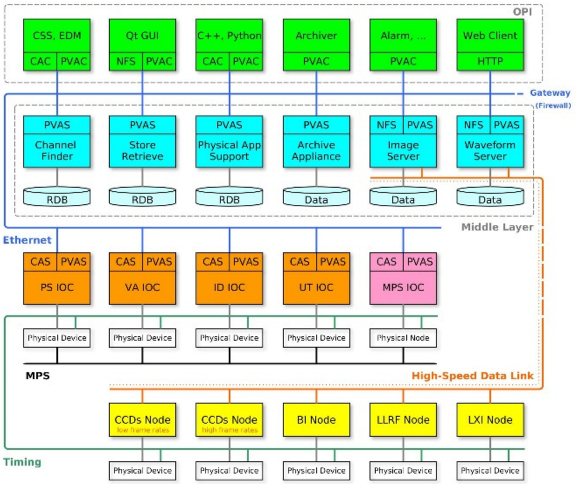

Figure 1: Architecture of the control system.

The middle layer consists of compute, storage and network devices. It provides the runtime environment for the whole control system. It also undertakes the centralized processing tasks for image and stream data acquisition system.

The device control layer is responsible for the facility-wide input and output device control, such as magnet power supply control, vacuum gauge control, stepper motor control and so on. The machine protection system will be also implemented in this layer. They are the basis components of the control system.

The data acquisition layer is designed for the high speed image and stream data acquisition, processing and storage. It involves the beam and laser diagnostics, microwave related system. Some custom software will be used at this layer.

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HEPS CONTROLS STATUS UPDATE*

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Abstract

The High Energy Photon Source (HEPS) is a planned extremely low emittance synchrotron radiation based light source located in suburban Beijing which requires high precession control systems for both accelerator and beamline controls. This paper outlines the overall design for control systems, including equipment control, fast orbit feedback, machine protection, controls network, database, high-level application architecture, and physics applications. Early plans for beamline controls are also reported.

INTRODUCTION

An ultra-low emittance and high brightness 4th generation synchrotron light source, the High Energy Photon Source (HEPS) designed by the Institute of High Energy Physics (IHEP), will start its construction by the end of 2018. To reach the high goals listed in Table 1, especially a scale of the order of about 2500 magnets and similar number of diagnostic devices, it is necessary to have accurate installation, state-of-art equipment and high precision controls with intelligence. Therefore, the control systems are vital for the HEPS which includes not only traditional control architecture design but also quality control for the project. Also, the HEPS control system covers not only the accelerator but also the first 14 beamlines which will be constructed at the same time. To build such a complex accelerator based user-facility, it is necessary to have an overall complete design for the control systems.

The HEPS control system design and test environment setup progress which includes database work, and accelerator and beamline controls, as well as the quality control tools being developed at this early stage of the project will be described in this paper.

Table 1: HEPS Main Parameters

Main parameters	Value	Unit
Beam energy	6	GeV
Circumference	1360	m
Emittance	58 (<40 anti-bend)	pm·rad
Beam current	200	mA
Brightness	$>10^{22}$	Phs/s/mm^2/mrad^2/0.1%BW
Injection	Top-up	
Bunch structure	680 bunch， high brightness mode 63 bunch， timing mode	

DATABASE WORK

In the modern data era, it is essential to record every useful data and store the data systematically in persistent stores. Furthermore, applications to utilize the data should be developed. Due to the large database work, it is necessary to divide the entire database into many nearly independent database modules and connect them via API (Application Programming Interface) or services. This way the database modules can be developed independently by many institutes and avoid the complexity of a single database. A few database modules can be merged via links of either device ID which is based on the role the device is played in an accelerator, or equipment ID which is merely a unique QR code or RFID.

Based on IRMIS [1], as listed in Table 2, there are 17 database modules identified. At this stage of the project, *i.e.* the design and early implementation phase, databases such as Parameter List, Naming Convention, and Magnet have been developed to suit the project's current needs. In addition, colleagues from another IHEP facility, the China Spallation Neutron Source (CSNS) is collaborating with the HEPS team to develop a Logbook and Issue Tracking database and application for CSNS's early operation need. Besides the 4 database modules currently under development, a few others like Accelerator Model/Lattice, Physics Data and Machine State, and Work Flow Control/Traveler have been developed by colleagues for other projects which can be migrated here easily. The rest of the database modules listed in Table 2 will be developed at later times while they are needed. HEPS select MySQL as the database primary tool. Details for the three under-developed databases are described below.

Table 2: Planned Database Work

Parameter List	**Logbook and Issue Tracking**	Cable
Naming Convention	Maintenance/Operation	Security
Magnet	Inventory	Alarm
Accelerator Model/Lattice	Survey and Alignment	Machine Protection/Interlock
Equipment and Configuration	**Work Flow Control/Traveler**	MPS Postmortem
Physics Data and Machine State	Document DB	

Design Parameter Database

This is a database which stores the essential HEPS parameters for keeping track of different design versions. The database schema was based on ESS design [2] with necessary modifications to fit HEPS own needs.

Naming Convention Database

For a large accelerator project like HEPS, everything has to be named according to strict rules or it is hard to manage the names. The HEPS Naming Convention database provides such a systematic tool for generating names automatically according to rules which will be applied to both accelerator and beamline experiment instruments.

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!CHAOS GENERAL STATUS REPORT

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Abstract

!CHAOS[1] (Control system based on Highly Abstracted and Open Structure) is now mature and is being employed in real operational contexts. A dedicated infrastructure, recently installed at the LNF Computer Centre, houses the framework and provides control services to different LNF installations. The !CHAOS native capability of fast storage, based on the use of a nonrelational database, has been finalized and tested with applications demanding high bandwidth. Thanks to its scalable design, the fast storage allows to accommodate multiple sources with sub millisecond timing. The EU (Execution Unit) node has also been delivered and turned out to be a "Swiss Army knife" for processing both live and stored data, inserting feedbacks and in general for correlating data acquired by the CU (Control Units) nodes. A key feature of the EU is a plugin mechanism that allows to easily integrate different programming and scripting languages such as LUA, C++, Python, also exploiting the ROOT framework, the well known scientific tool from CERN. A comprehensive description of the !CHAOS evolution, of its performances and of its use, both in scientific and industrial contexts, is presented.

INTRODUCTION

The !CHAOS project started with the ambition to create an innovative control framework exploiting software technologies developed for high performance web services and therefore capable to handle millions of users accessing the services and interacting with one another.

The framework was designed to be scalable and cloud aware and, as a result, suitable for application in many different contexts, beyond those required by the scientific community.

The right way to look at !CHAOS is as a SaaS that specializes in controls. In fact, we often refer to it with the neologism of *Control as a Service* (CaaS).

Moreover, !CHAOS ranks in that niche — still partially unexplored — between Control Systems and DAQ Systems. Indeed, the horizontal scalability of the framework allows fast storage for multiple data sources with sub-milliseconds timing, granting a centralized time synchronization among them of the order of milliseconds. This feature — embedded by design in the !CHAOS architecture — is fundamental to make cross correlations among many heterogeneous data and also opens to new applications such as diagnostic, maintenance and predictive maintenance of large scientific facilities and industrial plants.

Data handling is also greatly eased by the adoption of non-relational databases and BSON/JSON data representation throughout the system.

The !CHAOS framework is currently used both in industrial and scientific collaborations.

SYSTEM OUTLINE

Back-end Layer

The framework relies on back-end services which provide core services such as data caching and permanent storage. The back-end services are:

- the Distributed Object Caching (DOC) that continuously store the latest datasets representing all the physical and abstract entities acquired or computed by the system;
- the Distributed Object Storage (DOS) that enqueues the above datasets in a persistent database;
- the metadata storage that holds configurations and preferences data — both of the system itself and the elements under control — in a persistent database.

The key-features of all the services are that they (i) build upon non-relational logic and (ii) handle datasets consisting of BSON objects (which ultimately are blobs of bytes). As a result, different data structures can be directly stored as key-value datasets, thus without any extra data parsing or manipulation and the need of setting up many different table structures. Moreover, the inherent schemaless nature of non-relational databases, greatly speed-up, as in the case of DOS service, the writing of permanent data, for the benefit of the !CHAOS DAQ performance.

Each of the framework's core services is not binded to any particular software technology or vendor. Different commercial, or open source, software can be adopted — as explained below — to implement the back-end functionality, the choice depending on the specific needs of the context. On the contrary, it is essential that DOC, DOS and metadata storage services can run as multiple instances on multiple machines, which is a prerequisite for the horizontal scalability of !CHAOS.

The current release of !CHAOS employs Couchbase® for the DOC and MongoDB© for the DOS and metadata storage. Similar products have been successfully employed and other are currently under evaluation (such as redis and Cassandra).

Both Couchbase and MongoDB deliver distributed architecture and provide compute, storage, and processing workload partitioning to meet ever-changing requirements.

EtherCAT DRIVER AND TOOLS FOR EPICS AND LINUX AT PSI

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Abstract

A combined EPICS/Linux driver package has been developed at PSI, to allow for simple and mostly automatic setup of various EtherCAT configurations. The driver is capable of automatic scan of the existing devices and modules, followed by self-configuration and finally autonomous operation of the EtherCAT bus real-time loop. Additionally, the driver package supports the user PLC to manipulate EtherCAT data in real time, implements fast real-time (single cycle) slave-to-slave communication (skipping EPICS layer or PLC completely), features guaranteed one-shot trigger signals otherwise not supported by EPICS and much more.

INTRODUCTION

For the modules and devices equipped with the EtherCAT bus interface [1], a general, real-time software interface was needed for the integration in the existing accelerator control system, both for existing facilities like SLS (Swiss Light Source) and HIPA (High Intensity Proton Accelerator), and for facilities and systems being built at the time this document was created, such as SwissFEL [2] (Swiss X-Ray Free Electron Laser).

First, we have tested the existing solutions, both related and unrelated to our controls system of choice, EPICS. Unfortunately, none of the existing commercial and non-commercial solutions we have reviewed and tested was able to cover and satisfy all of the requirements for the EtherCAT support at PSI.

CONCEPTS

Providing full support for such a wide range of systems and applications in a single package presented a problem since not every requirement or possible usage scenario could have been satisfied with a single piece of software.

EPICS control system support requires its own type of dedicated device support driver. Unlike its kernel counterparts, EPICS driver has to run in Linux userspace, since EPICS system itself is a userspace application. Aside from EPICS, the system has to support other types of applications.

To make things more complicated, the applications that are supposed to use the system are running in both userspace and kernelspace. This, of course, requires distinctively different structure of the supporting interfaces and practically double the work needed to create the system and maintain it later. Real-time applications can be created to run in either userspace or kernelspace, which in turns mean at least two separate local APIs had to be created.

EtherCAT Data Addressing

To describe an address of a given EtherCAT data entry, the following IDs have to be included:

- *master number* (since there can be multiple masters running on the same host),
- *domain number* (domain is an arbitrary, user-defined collection of PDO (Process Data Object) entries sharing the same buffer memory, EtherCAT packages and network exchange frame rate),
- *slave number* (slave is simply another name for an EtherCAT Module),
- *synchronization manager number* (synchronization managers, also known as SyncManagers or SMs, group EtherCAT PDO objects by their exchange direction (input/output) and other, manufacturer or end-user defined criteria),
- *process data object number* (process data objects, or PDOs, group entries by some arbitrary purpose defined by the manufacturer of the EtherCAT module, or if a module supports it, by end-users) or process data object entry number (process data object entries, or PDO Entries, hold the actual data exchanged by the module).

To solve this problem, we have devised a new addressing schema for EtherCAT data, as depicted in Fig. 1.

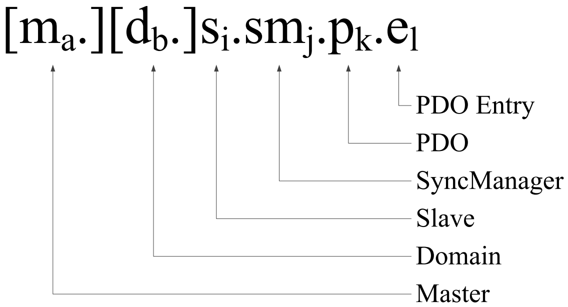

Figure 1: New schema for EtherCAT data addressing.

Master (**m**$_a$) and domain (**d**$_b$) can be omitted when a=0 or b=0, i.e., when the first, default master and domain are used. Similarly, the PDO entry (**e**$_l$), PDO (**p**$_k$) or SyncManager (**sm**$_j$) can be omitted as well (in that order), when the user wants to address multiple entries included in a larger parent container, instead of a single entry.

The possible modifiers or addressing modes (as of v2.0.6) are:

- `[.o<offset>]` - **forced offset** (in bytes). This allows shifting of the starting address of the PDO entry in the buffer, effectively allowing for partial reading of the entries or using certain “tricks” to reach otherwise unreachable or hard to reach content
- `[.b<bitnr>]` – **forced bit extraction**, allows extraction of single bits from any larger PDO entry data, regardless of its original type or length
- `[.r<domregnr>]` – **domain register addressing**, replaces address modifiers *s, sm, p* and *e*, using rela-

BLISS – EXPERIMENTS CONTROL FOR ESRF EBS BEAMLINES

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Abstract

BLISS is the new ESRF control system for running experiments, with full deployment aimed for the end of the EBS upgrade program in 2020. BLISS provides a global approach to run synchrotron experiments, thanks to hardware integration, Python sequences and an advanced scanning engine. As a Python package, BLISS can be easily embedded into any Python application and data management features enable online data analysis. In addition, BLISS ships with tools to enhance scientists user experience and can easily be integrated into TANGO based environments, with generic TANGO servers on top of BLISS controllers. BLISS configuration facility can be used as an alternative TANGO database. Delineating all aspects of the BLISS project from beamline device configuration up to the integrated user interface, this paper will present the technical choices that drove BLISS design and will describe the BLISS software architecture and technology stack in depth.

BLISS PROJECT SCOPE

The BLISS project brings a holistic approach to synchrotron beamline control. The scope of the BLISS project goes from hardware control up to the end-user interface. BLISS does not include data analysis, which is devoted to another software package at ESRF called *silx* [1].

CONFIGURATION

The BLISS configuration entity, a.k.a **Beacon**, aims to provide a complete and centralized description of the entire beamline. BLISS distinguishes between 2 kinds of configuration information: either configuration is **static**, as a stepper motor axis *steps per unit*, ie. the configuration information will not change over time once the object is configured ; or the configuration is subject to change, like a motor velocity for example. In this case, this is called a **setting** and settings are all backed up within the redis database [2].

Static Configuration

The **static** configuration consists of a centralized directory structure of text based files, which provides a simple, yet flexible mechanism to describe BLISS software initialization. The *YAML* [3] format has been chosen because of its human readability (cf. Figure 1).

BLISS is an object oriented library and its configuration follows the same model. Objects are identified in the system by a unique **name**. BLISS reserves the YAML key *name* as the entry point for an object configuration.

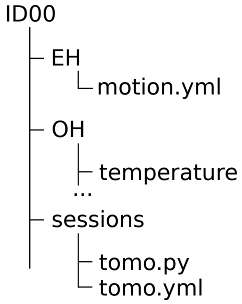

Figure 1: YAML tree example.

Each particular BLISS class may choose to profit from the BLISS configuration system. The BLISS configuration is powerful enough to describe not only control objects like motors, counter cards or detectors but also user interface objects like sessions or procedures.

The following YAML lines exemplify motor and session configurations:

```
# motion.yml
class: IcePAP
host: iceid311
plugin: emotion
axes:
- name: rotY
  address: 3
  steps_per_unit: 100
  acceleration: 16.0
  velocity: 2.0
```

```
# tomo.yml
class: Session
name: tomo
config-objects: [rotY, pilatus, I, I0]
setup-file: ./tomo.py
measurement-groups:
- name: sensors
  counters: [I, I0]
```

Settings

Beacon relies on *Redis* to store **settings**, ie. configuration values that change over time, and that needs to be applied to hardware equipments at initialization time. This allows to be persistent across executions. Taking again the motor example, if a motor velocity is set to a certain amount from a BLISS session, when it is restarted the last known velocity is applied to the axis. Settings values use *Redis* structures: settings can be hashes (mapped to a Python dictionary), lists, and scalar values. BLISS offers a

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A GENERAL SOLUTION FOR COMPLEX VACUUM SYSTEM CONTROLS

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Abstract

At the National Synchrotron Light Source II (NSLS-II) there are many different ultra-high vacuum system configurations on the unique beamline end-stations. The proposed controls solution attempts to capture the requirements of all of these configurations with a single standard logic and graphical user interface. Additional design considerations include: resource management for multiple users, providing a high level of abstraction to simplify operation for users, providing a high level of flexibility to do nonstandard operations, minimizing shock from pressure differentials when opening valves, supporting a variety of pumps, and maximizing pump lifetime. At NSLS-II it was determined that all vacuum configurations can be captured by the composition of three standard objects: a "rough vacuum group", "high vacuum group", and a "smart vacuum manifold" which implements a blocking queue. These objects can be flexibly linked together to meet the needs of the beamline experiments. This solution is platform independent, but implemented and tested here using Pfeiffer vacuum Pumps, Allen Bradley PLC, EPICS, and Control System Studio (CSS).

INTRODUCTION

At the National Synchrotron Light Source II (NSLS-II) there are many different ultra-high vacuum system configurations on the unique beamline end-stations. The end-station vacuum systems often differ from the vacuum systems of the rest of the accelerator and beamline in that they frequently need to have sections vented. They also often have unique vacuum requirements for their experiments. End-station vacuum systems often incorporate roughing pumps and turbo pumps to meet their pumping speed and throughput requirements. End-station vacuum systems also incorporate ion pumps and NeG pumps to achieve the best possible vacuum. Some configurations are quite simple, for example: a single vacuum chamber with a vacuum system consisting of a roughing pump, isolation valve, turbo pump, and a gate valve. Other vacuum system configurations are more complex. Figure 1 shows a vacuum system configuration that is typical for a more complex end-station. Vacuum system configurations can vary greatly between end-stations.

There are challenges that come with working with these vacuum systems. Multiple users can be executing independent operations on the vacuum system that require access to the same resource. Currently this is handled by staff coordination. Due to the complexity of these vacuum systems, users are often uncomfortable with executing vacuum system operations. Even expert staff can make mistakes. This project attempts to address these challenges, and simply the operation of end station vacuum systems.

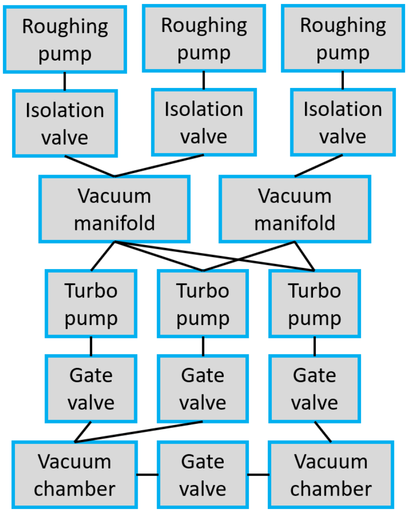

Figure 1: Example vacuum system configuration.

REQUIREMENTS

The goal of this project is to create a modular standard logic and Graphical User Interface (GUI) that supports all of the different end-station vacuum configurations. The design should simplify user operation, by automating common operations, and by providing an abstraction to hide the complexity of the system. The automation of the common operations should reduce the chance for human error and improve response to faults. Users of the system may also need to do a non-standard operation not supported by automated logic, so the solution must also allow for manual control of all output signals. The GUI should clearly and simply communicate vacuum status to its users. The modular standard logic and GUI should make it more efficient to automate new vacuum systems by allowing a copy and paste of standardized modules and linking them together to meet the vacuum requirements.

SYSTEM DESCRIPTION

The end-station vacuum systems at the NSLS-II are composed of a small set of hardware devices: Roughing pumps, vacuum gauges, flow meters, angle valves, gate valves, turbo pumps, ion pumps, and NeG pumps. The signals of the vacuum devices have been wired to distributed PLC I/O modules. The distributed I/O communicates to the PLC via ethernet. At NSLS-II we use EPICS, which is a distributed real-time control system and SCADA, which allows us to integrate many independent control

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DEVELOPING AND VALIDATING OPC-UA BASED INDUSTRIAL CONTROLS FOR POWER SUPPLIES AT CERN

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Abstract

The industrial control systems of CERN's experiments are undergoing major renovation since 2017 and well into CERN's second Long Shutdown (LS2) until the end of 2019. Each detector power-supply control system runs several hundred software instances consisting of many different components in parallel on a large scale, broadly distinguishable as servers and clients. Our accumulated experience during LHC runs proves that some complex control issues are impossible to detect using stand-alone components on a small scale only. Furthermore, new components must be developed well before the electronics becomes available, without impact on operations. Moreover, during LS2, the improved and now widely established Open Protocol Communication Unified Architecture (OPC-UA) replaces OPC-DA as middleware protocol. For these reasons, we developed a simulation environment to emulate the real, and valuable, CAEN power-supply electronics underneath the OPC-UA servers. This distributed simulation is configurable to mimic and exceed the nominal conditions during production and provides a repeatable setup for validation. This paper discusses the functionality and use of this simulation service.

WHY A SIMULATION?

The control system for the CERN experiments can be segmented into three layers. Firstly, the electronics layer for power supplies and many other components, which includes commercially available modules connected to the detector sub-parts. Some CERN experiments need many thousands of power channels laid out in “electronic trees” spanning a wide variety of characteristics and behaviour, generally using networked modules from different commercial vendors running black box firmware.

The second layer provides the OPC-UA [1,2] interfaces to the different kinds of power supply modules. OPC-UA provides standardized abstraction and communication, and replaces its now obsolete predecessor OPC-DA. Several tens of server instances connect to the power channels for a typical experiment, each server with its specific electronic tree.

Lastly, the client layer provides classical supervisory control and data acquisition (SCADA) services including logging, error handling and analysis, history data storage and functional abstractions like finite state machines and interfaces for specific detector functionality. The two uppermost layers rely entirely on the accurate and robust translation of the physical electronic trees into the software representation with the intended functionality. A commercial object-orientated SCADA system, WinCC-OA [3], is used to realize much of the upmost layer. This now mature control system has to undergo updates and functional fixes, which all have impact on mission criticality in some way, but where their deployment should not require any dedicated production time.

The investigation of issues and the actual deployment of updates requires very careful coordination and is, generally, a delicate process for the two following reasons. Firstly, still affordable laboratory tests can never approach the same complexity, scale and diversity as a real running system with inputs and errors. Any new versions of control components, concerning also new versions of the electronics, need testing and validation through all control layers. Problems related to scaling, which were reproducible in the experiments in the past but not in laboratory tests, and could not be confirmed by the vendor either, need to be investigated on appropriate scale and complexity, to then be followed up adequately.

Secondly, a system with delicate high voltage detector-hardware must not be used for testing critical and safety related software. Even if one would take the risk, it would be very hard to identify and re-produce any complex failure scenario for further debugging. A satisfying validation for a working control system of that scale could be obtained by performing global centralized “dry runs” using real electronics, but disconnected high voltage output stages, yet such runs are deemed impractical and too expensive. For these reasons a scalable low-level platform which provides **ven**dor **u**nified **s**imulation (VENUS) for power supplies together with a realistic behaviour is needed as an efficient and flexible solution which can also support training and development prototypes.

REQUIREMENTS

Scale and Validation

Both issues, scale and validation, can be efficiently addressed with a simulation environment which emulates the electronics of the first layer. Large scale “developer tests” are possible, being much more independent on whether the electronics is available, in production, or even only a planned purchase. Replaying complex and demanding scenarios should push various controls software components in the upper layer to their respective limits, thus providing useful stress tests. If scale and complexity of the production systems can be significantly exceeded in the simulation, we assume with good confidence that our systems are adequately validated.

Performance and Complexity

Changing parameters in the electronic tree create events with associated data payload, which are pushed upwards to the subscribing server. Event rates of several kHz are

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WIRELESS INTERNET OF THINGS (IoT) APPLICATION IN THE TLS

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Abstract

The internet of thing is applied in the accelerator more frequently than before. There are many advantages in data acquisition and control-oriented applications, for example, easy to distribute remotely and less cables needed, low noise generated, many commercial interfaces for choosing. The stable wireless communication is also applied in the measurement system. The high reliability and security of wireless communication with server and client structure is introduced. The structure design and implementation of IoT are summarized in this report.

INTRODUCTION

The applications of IOT are based on Raspberry Pi 3 and Intel Celeron N3050 system in the operation group.

The Raspberry Pi 3 is applied in the temperature measurement with angalog/digital interface. The Raspberry Pi3 system is show in Figure 1.

Hardware specifications are listed:

- Broadcom BCM2837B0, Cortex-A53 (ARMv8) 64-bit SoC @ 1.4GHz
- 1GB LPDDR2 SDRAM
- 2.4GHz and 5GHz IEEE 802.11.b/g/n/ac wireless LAN, Bluetooth 4.2, BLE
- Gigabit Ethernet over USB 2.0 (maximum throughput 300 Mbps)
- Extended 40-pin GPIO header
- Full-size HDMI
- 4 USB 2.0 ports
- CSI camera port for connecting a Raspberry Pi camera
- DSI display port for connecting a Raspberry Pi touchscreen display

Figure 1: Raspberry Pi 3 system.

The Intel N3050 system is apllied in the various displays these include of alarm, security monitor system. The systme is shown in Figure 2. Intel Celeron N3050 Kit is an entry-level, small-footprint. Equipped with a dual-core Celeron® processor, this Intel NUC includes new features. These features include items such as a VGA port, SDXC card slot and TOSLINK audio output. It also continues to offer 4x USB 3.0 ports, 4K video support, and 802.11ac Wi-Fi. The hardware specifiaction are lists:

(a) Model A (b) Model B

Figure 2: Intel Celeron N3050 system. There are two difference form factors are applied. Model A is suppoted in 4 K display and IR remote control, model B is applied in the weak wireless signals area with high gain antenna.

- Soldered-down dual-core Intel® Celeron® processor N3050 with up to 6 W TDP
- 4K HDMI display
- USB 3.0/SATA6.0
- IR Receiver Sensor
- Intel® Wireless-AC 3165 + Bluetooth 4.2
- 10/100/1000 ethernet

This system are applied in the 4K display. Alarm and security monitor are adapted in this application.

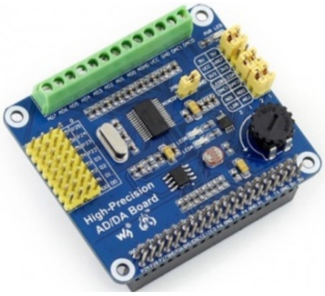

Figure 3: High-precision AD/DA convert.

Wireless lan and bluethooth interface are built in this low cost production that can provide amout of arrangement with simple DC power and manpower. In most time, the doors of storage ring tunnel are close. This is useful in the temporary measurement and system diagnostic for this short period time.

INTERFACE OF IoT

Analog Interface

Since there are no AD/DA functions on Raspberry Pi GPIO interface, this may restrict the application development on Raspberry Pi sometimes. Hence, we have chosen high-precision AD/DA board from Waveshare

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DATA ARCHIVING AND VISUALIZATION OF IRFEL*

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Abstract

An Infrared Free Electron Laser Light (IRFEL) is being constructed at National Synchrotron Radiation Laboratory. The EPICS Archiver Appliance provides the functions of historical data acquisition, archiving, migration, retrieval and management in the IRFEL facility. A Single-Page Web Application is developed for the data visualization based on Vue.js framework and Highcharts JavaScirpt library. A unified interface is developed for the visualization to integrate multiple data sources and provide the same retrieval entry of the historical data from EPICS Archiver Appliance, the real-time data from EPICS IOC, the statistical data from database and the alarm information from the Phoebus. This paper will describe the implementation details of data archiving and visualization of IRFEL.

INTRODUCTION

Tunable Infrared Laser for Fundamental of Energy Chemistry (FELiChEM) is the significant scientific instrument, which is supported by the National Natural Science Foundation of China in 2013. Infrared Free Electron Lasers (IRFEL) is the core part of FELiChEM, which can accelerate beam to 60MeV and generate middle-infrared and far-infrared laser [1]. The control system of IRFEL is developed based on Experimental Physics and Industrial Control System (EPICS) [2].

The operation of a particle accelerator complex is a long-term experiment. It is essential to record Process Variables (PVs) for further data analysis. With the continuous development of EPICS, a series of data archiving systems has been released in the EPICS community, such as, Channel Archiver, RDB Channel Archiver and the EPICS Archiver Appliance [3]. The EPICS Archiver Appliance (AA) is used as the data archiving tool for the IRFEL. A Web-based GUI is developed for the data visualization. It not only provides the function of historical data query, but also integrates real-time data, statistical data and alarm information into a web application. This paper will describe the implementation details of data archiving and visualization of IRFEL.

SYSTEM ARCHITECTURE

The EPICS Archiver Appliance (AA) is a data archiving tool released in the EPICS community and provides the functions of data acquisition, storage, migration, retrieval and management in the IRFEL facility [4]. AA divides the data into three types: short term store (in RAM disk), medium term store (in local SSD disk) and long term store (in NFS).This mechanism makes AA have high data retrieval performance, which is helpful to machine status analysis and fault diagnosis.

Figure 1 shows the overall structure of the whole system. It is a typical web application and implements the complete separation of the front and back end. The data displayed on the front end can be divided into four types: real-time status, historical data, statistical data and alarm information. As a reverse proxy server, Nginx provides a unified interface for querying these four types of data. The initial sources of the data are all the IOCs in the control system, but they are processed through different ways. The implementation will be described in detail about how to archive, store, process and visualize the data in the following sections.

IMPLEMENTATION OF SERVER SIDE

Real-time Data

It is necessary to display the real-time state of accelerator (such as beam current, running state, etc.) on the web page. However, data archiving tools generally have some time delay to write data to the database and real-time data can not be obtained from archiving tools. In order to solve this problem, the real-time state push is implemented by WebSocket communication from IOC to web page directly.

The WebSocket protocol provides a way of creating web applications that support real-time bidirectional communication between clients and servers. Figure 2 shows the principle of the status push program. Its core is the *Websocketd*, which is a small command-line tool that will wrap an existing command-line interface program, and allow it to be accessed via a WebSocket. As long as you can write an executable program that reads STDIN and writes to STDOUT, you can build a WebSocket server in any programming language [5].

A python script is developed to monitor the PV change in IOC Record via Channel Access and writes them into STDOUT. Any text printed by the process to STDOUT shall be sent as a WebSocket message whenever a newline is encountered. In this way, the JavaScript script running in the browser can get the latest change values of the PVs through the WebSocket and display them on the web page.

Historical Data

The EPICS Archiver Appliance comes with a web interface that has support for various business processes. The web interface communicates with the server principally using HTTP/JSON. There is a rich catalog of business logic that lets the user add/modify/delete PVs from the archiver. This design provides convenience for its integration with other systems. Therefore, client application can get historical data directly from this interface.

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INNOVATIVE GRAPHICAL USER INTERFACES DEVELOPMENT: GIVE THE POWER BACK TO USERS

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Abstract

Graphical User Interfaces (GUIs) for Supervision, Control and Data Acquisition Systems (SCADA) are usually oriented to specialist users. In big organizations like CERN, where different teams play the roles of operators, scientists and instrumentation specialists, providing a unique or static user interface usually results in a situation of dissatisfaction for everyone. Providing distinct user interfaces for each type of user increases the development and maintenance effort and makes the software evolution heavier. The approach taken in the design and development of GUIs for radiation and environment protection at CERN addresses these issues by integrating user interface changes as an embedded software functionality. Key users were provided with a tool to build, deploy and maintain their own tailor-made user interfaces, in a graphical way and without the necessity of learning any kind of programming or scripting languages. Other benefits observed from this solution includes the reduction of the resources spent on the support and maintenance and the increase of the frequency of GUIs updates, executed without compromising the underlying control system. This paper describes the innovative design that was implemented.

INTRODUCTION

The Health Safety and Environment Unit at CERN provides a SCADA system for the radiation protection and environment monitoring of particle accelerators, experiments and the environment. The system called REMUS [1] (Radiation and Environment Monitoring Unified Supervision) runs 24/7 hours 365 days a year.

REMUS is a large system in its class (600.000 tags) interfacing 550 monitoring stations built convening 75 device types and 3000 measurement channels. Its GUI has 600 different synoptic views used by around 50 concurrent users from a total population of 200 authorised users. Those users have different roles, needs and expectations of the system.

Naturally, the GUIs require frequent updates to adapt to the ever changing CERN environment (installation of new instrumentation or regular changes of the instrumentation type or location).

The design of REMUS addresses two problems by design:

- Evolution and extension of the GUIs impact many users with different needs, sometimes conflicting.
- Frequent GUI updates are resource demanding tasks.

The REMUS approach to deal with these challenges is to provide the final users with the possibility of building their own GUIs.

BUILDING USER INTERFACES FOR SCADA SYSTEMS

The usual approach to design SCADA GUIs consists of making a schematic representation of the target process, installation or technical facility (synoptic views). Then placing widgets that represent devices, providing animated readings for supervision purposes and commands to control the underlying process. If the system is large, it may be necessary to present it in smaller parts or sub-systems in order to reach a lower level of details and to add a navigation mechanism that facilitates visualization and operation for users.

The attained level of detail is often the one of individual equipment, sensors and actuators under supervision and control from which the system is doing data acquisition. In order to complete the SCADA GUI it is necessary to add an access control mechanism to in order to grant the proper level of access rights to the authorised users.

BUILDING REMUS GUI

REMUS users have differing needs and expectations from the system. REMUS provides interfaces for operators of accelerators and experiments, physicists, instrumentation specialists, radiation protection engineers, environmental engineers, CERN Fire Brigade, instrumentation maintenance teams and the software support team. Providing a unique GUI for all these users regardless of their role is not a good approach as there is no interface that can suit everybody.

User interfaces need to adapt to the diverse user roles and require frequent modifications to handle the continuous changes in the supervised instrumentation.

The REMUS interface is organized in a tree-structure of synoptic views displaying CERN surface and underground areas. Widgets representing hardware devices and measurement channels are displayed on the synoptic views. There are different versions of widgets for each device type, addressing specific levels of detail required by different types of users.

REMUS Applications

In order to provide users with the most suitable interfaces, REMUS has a special kind of users named *Application Administrators*, who takes care of building interfaces for all other users. Administrators are neither part of the REMUS support team nor software developers.

A UNIVERSAL SYSTEM BASED ON WEBSOCKET AND JSON FOR THE EMPLOYMENT OF LabVIEW EXTERNAL DRIVERS

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Abstract

One of the heaviest workloads when installing a Control System on a plant is the development of a large number of device drivers. This is even more true in the case of scientific facilities for which you typically deal with many custom devices and legacy code. In these cases, it is useful to consider the Rapid Application Development (RAD) approach that consists in lessen the planning phase and give more emphasis on an adaptive process, so that software prototypes can be successfully used in addition to or in place of design specifications. LabVIEW [1] is a typical RAD oriented development tool and is widely used in technical laboratories where many standalone programs are developed to manage devices under construction or evaluation. An original system that allows software clients to use external LabVIEW drivers is presented. This system, originally created for the !CHAOS Control System [2], is entirely written in LabVIEW and is based on JSON messages transmitted on a WebSocket communication driving LabVIEW VIs through dynamic calls. This system is completely decoupled from the client and is therefore suitable for any Control System.

DESCRIPTION OF THE ELF SYSTEM

The project called ELF (External LabVIEW Functions executor) stemmed from the need to reuse as much as possible the huge amount of software — especially device drivers — already written in LabVIEW, to speed up the implementation of new controls currently being implemented with !CHAOS, a control framework developed at the National Laboratories of Frascati of the INFN.

As the project evolved, its usefulness was also evident not only for the re-use of existing LabVIEW Virtual Instruments (VIs) but also as a proficient method for the collaborative development of complex LabVIEW programs. In fact ELF provides for the VIs acting as drivers to be called by reference and not be wired into other G code, which greatly facilitates the team development.

Ultimately, this work consists in the realization of an environment able to have LabVIEW VIs execute in a well managed and standardized manner, upon calls coming from a client application written in any language.

The project requirements where:

- to adopt widely used communication protocol and data-interchange format for the communication between the client and ELF;
- to write the whole ELF code in G: the LabVIEW graphical programming language;
- to be able to deal with simultaneous calls from multiple clients;
- to adopt a unique template for the VIs to be executed and a well defined syntax for their call;
- to realize a modular architecture, allowing its usage both from non-LabVIEW and LabVIEW clients;
- to get such performance that it could be used in a wide range of applications.

It is worth to point out that the ELF employment is non restricted to the call of device drivers but extends to any VIs complying with the adopted template and syntax.

COMMUNICATION BETWEEN CLIENT APPLICATIONS AND ELF

First we must clarify what is meant — in this context — for client application (*client* from now on). We therefore define as client any program that accesses the ELF to perform a set of predefined functions implemented in LabVIEW and obtain results back, if any.

As an example, in our case the typical client is a !CHAOS Control Unit (CU): the control node that continuously acquire data from a device and operate it. To access a physical device, the CU performs a RPC by using a C++ *skeleton* that relays the function *opcode* along with its arguments to a *stub* that eventually runs the actual driver. In !CHAOS, drivers are usually implemented as C++ programs but, if they are available as LabVIEW VIs, the *skeleton* can direct the calls towards the ELF system which acts as *stub*.

The communication between a client and ELF meets the client/server model, with ELF playing the role of server, and follows the WebSocket [3] protocol.

WebSocket provides full-duplex communication between nodes over a single TCP connection with data minimally framed, to the benefit of real-time data transfer.

It provides a standardized way for the server to send content to the client without being first requested, and allowes messages to be passed back and forth while keeping the connection open. The WebSocket handshake starts with an HTTP request/response then — once the connection is established — the communication switches to a bidirectional binary protocol which doesn't longer conform to HTTP. This method is advantageous since HTTP *flows* through proxies and therefore it is possible to open connections even from remote clients laying within a NAT, which is very convenient for distributed system where remote control nodes can be spread anywhere (as in the case of !CHAOS).

As data-interchange format it has been adopted JSON (JavaScript Object Notation) because it is lightweight and also because JSON documents are ultimately strings, which facilitates the passage of different data formats to LabVIEW VIs.

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SWISSFEL ELECTRON BEAM DIAGNOSTICS TOOLS AND THEIR CONTROL SYSTEM COMPONENTS

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Abstract

The main driving part of the X-ray free electron laser facility (SwissFEL) at Paul Scherrer Institute (PSI) is a compact electron linear accelerator (linac). The machine is highly optimized to generate a superior FEL radiation with the lowest suitable electron beam energy. In order to meet extremely stringent SwissFEL require-ments for electron beam quality and stability, a variety of advanced beam diagnostics tools were developed and implemented at PSI. All these tools are integrated into the SwissFEL control system. The paper describes basic control elements of advanced electron beam diagnostics tools and their operational performance.

INTRODUCTION

The X-ray free electron laser facility (SwissFEL) at Paul Scherrer Institute (PSI) is driven by a normal conducting linear accelerator (linac), which generates electron bunches with a repetition rate of 100 Hz and charges in the range from 10 pC to 200 pC. In order to provide user experiments with extremely stable, brilliant and ultrashort (~10 fs) photon pulses, which are tunable in the whole wavelength interval from 0.1 to 7 nm, the operations of the SwissFEL machine pose very challenging demands on a number of relevant electron beam parameters, such as the bunch energy, charge, length, arrival time, compression, transverse position, profile, etc. A series of Beam Diagnostics Monitors (BDMs) developed at PSI allows one to obtain all those parameters online. Each BDM is a beam instrumentation device dealing with a particular beam parameter (e.g., arrival time).

In the SwissFEL control system environment, BDMs are implemented as Beam Diagnostics Tools (BDTs), which are based on the PSI Generic Beam Diagnostics Electronics (GBDE) platform in the VME standard and Advanced Data Processing and Control System (ADPCS) setup concept.

GENERIC BEAM DIAGNOSTICS ELECTRONICS PLATFORM OVERVIEW

The GBDE platform is schematically shown in Fig. 1. It combines BDM specific detectors and front-end electronics with common solutions for digitization, FPGA based digital signal processing and interfacing [1]. The platform is very efficient for interacting with control systems.

The analogue signals from BDM detectors are collected by front-end electronics, which is implemented as mezzanine boards sitting on standard PSI Analogue Carrier (PAC) cards. The electronics is in charge of signal conditioning, which is detector specific and typically deals with the optimization of dynamic ranges, signal-to-noise performance, input/output levels, etc.

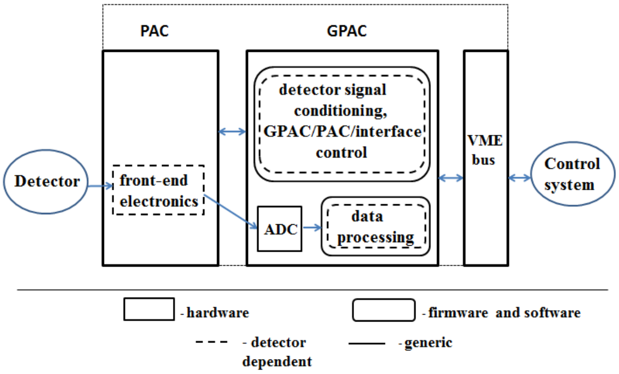

Figure 1: PSI GBDE platform schematics.

PAC output signals are read out by Generic PSI ADC Carrier (GPAC) cards, where they are digitized by fast ADC mezzanine boards and then processed digitally. The major ADC board type that is used for SwissFEL beam diagnostics applications has eight 12 bit 500 Msps ADCs. The ADC sampling clock is provided externally by the SwissFEL reference distribution system [2] or a locally generated BDM clock signal. GPAC cards also regulate GPAC working parameters and handle the communication with the external control system (via the VME bus) and electronics, such as, for instance, PAC cards. All GPAC control and data processing functions are supported by the firmware and software running on several FPGA and embedded CPU (PowerPC) modules.

Two VME bus memory blocks are allocated for the communication of GPAC cards with the control system. Memory mapped GPAC control and status registers make up the GPAC Control Block (GCB). The GPAC Data Block (GDB) comprises the results of signal processing by GPAC firmware and software.

We note that the GPAC firmware, which is in charge of the communication with the control system, is common for beam diagnostics applications. In particular, it maps GPAC control and status registers into GCB, timely reacts on commands from control applications by monitoring this block, and generates the VME bus interrupts. On the other hand, the ADC outputs are processed by firmware and software, which are detector dependent. In major applications, the data processing is triggered externally.

The GBDE platform gives beam diagnostics physicists and electronics engineers a generic way of the BDM development. As the result, their main efforts are concentrated on BDM specific electronics, firmware and software.

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UPDATE ON THE STATUS OF THE FLUTE CONTROL SYSTEM

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Abstract

The first phase of FLUTE, a new linac based test facility and THz source, is currently being commissioned at the Karlsruhe Institute of Technology (KIT). It consist of an RF photo gun and a traveling wave linac accelerating electrons to beam energies of 40 to 50 MeV. The control system is based on a virtualized infrastructure running Ubuntu Linux and Linux KVM. As base for the SCADA system we use EPICS 3.15 with Control System Studio (CSS) for the GUI. The long term data storage is provided by a Cassandra NoSQL database. This contribution will present the architecture and the current status of the FLUTE control system.

INTRODUCTION

FLUTE [1] is a new R&D linac accelerator (see Fig. 1) offering beam energies of 7 to 41 MeV for the development of accelerator technology, new diagnostics and instrumentation for fs bunches. It will be used as a test facility for the study of bunch compression with all related effects and instabilities like space charge, coherent synchrotron radiation (CSR) as well as the different generation mechanisms for coherent THz radiation. Furthermore it will serve as a broad band accelerator-based source for ultra-short and intensive THz pulses, e.g. for time- & frequency-domain spectroscopy of kinetic processes.

CONTROL SYSTEM OVERVIEW

The design of the FLUTE control system [2] is based on EPICS 3.15 with Control System Studio (CSS) as the main operators interface to the control system.

The DAQ has been driven by the demand to make systematic studies of the beam compression and the generation of THz radiation. The pulse synchronous (10 Hz) data-acquisition based on a Cassandra NoSQL database has to record for each pulse diagnostic information about RF pulses, laser pulses, pulse charge and of course the overall accelerator settings.

Operator GUI Concept

The top level panels of the operator GUI have an synaptic approach. A 3D model of the Accelerator is used to for easy orientation (see Fig. 2). An error is visually connected to the device and to the position along the machine. The corresponding control panel for the device can be opened by a direct link on the panel. In addition all device panels are included in a list, which can be used to navigate to the devices, grouped by their task. As the accelerator is in its first phase the starting overview panel shows the injector section. For each of the next sections there are also synaptic overview panels planned as well as for the complete machine.

Stepper Motor Control

The FLUTE accelerator and the KARA Beamlines are using the same inhouse developed stepper motor control and driver concept. For motion control, we use the OMS (Pro-Dex) 5 axis Ethernet based MAXNET controllers and as 2 phase motor drivers we use the BCD130.x family of MIDDEX electronic allowing up to 12800 micro steps per revolution. EPICS hardware integration was done with the Pro-dex OMS asyn motor base axis support. For axes using an encoder, we experienced the problem that the motors would sometimes move randomly. We could solve these problems by applying a patch that synchronizes the motor with the encoder position before every movement.

Timing System

The timing system for FLUTE is based on the hardware components from Micro-Research Finland [3]. We use the VME form-factor for both the event generator (EVG) and the majority of event receivers (EVRs). However, we do not use the VMEbus for controlling these boards. Instead, we use their Ethernet interface to control them using a UDP/IP-based protocol.

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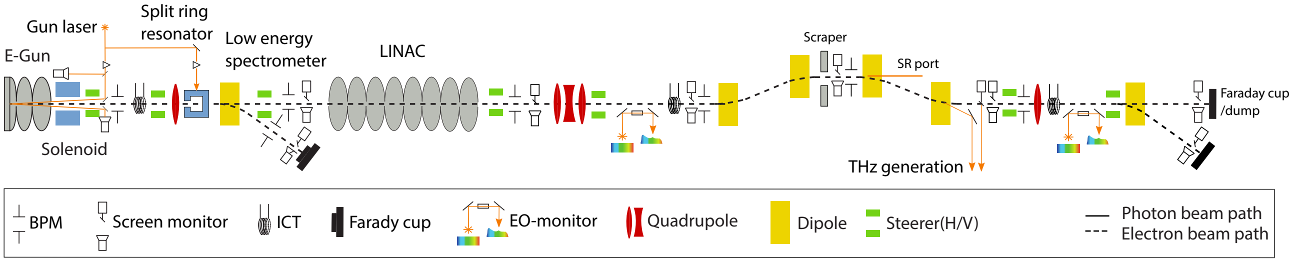

Figure 1: Scheme of the FLUTE accelerator with all installed and planned components [1].

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ETHERCAT SOLUTION FOR THE TPS CONTROL SYSTEM

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Abstract

The EtherCAT real-time Ethernet technology is now widely used in the field of industrial automation. This paper is to evaluate and establish the EtherCAT (Ethernet for Control Automation Technology) solution for digital and analogue I/O and motion control in accelerator applications. Thanks to developments at the Diamond Light Source, EtherCAT is integrated into EPICS with support for most devices of a general data type. Preliminary tests and plans are summarized in this report.

INTRODUCTION

The Taiwan Photon Source (TPS) is a low emittance, high brightness synchrotron light source, located in Hsinchu, Taiwan. New control technologies have begun to emerge in the past few years and we pay specific attention to the EtherCAT technology [1], which is a fieldbus system based on Ethernet and was developed by Beckhoff Automation [2] in 2003. It has become one of the mainstream communications interfaces for connecting to PLCs, sensors, servo motors, I/O and other automation equipment. The goal of EtherCAT development is to enable Ethernet applications to reduce data update time, lower communications jitter and reduce hardware costs for application to automation. The EtherCAT protocol is standardized in IEC 61158. The EtherCAT master sends a telegram through to each slaves and each EtherCAT device reads the data and inserts its data into the frame as it moves downstream. EtherCAT supports almost any topology, such as line, tree or star.

Several support programs were developed for communication between EPICS IOC and the EtherCAT master. At the Diamond Light Source (DLS) support is being developed based on a scanner process through the IgH EtherCAT which can transfer data between EPICS IOC and EtherCAT master [3] through the UNIX socket. Based on IgH EtherCAT, the PSI [4] also develops an EtherCAT driver, ecat2, for the same purposes. The HE Youngcheng [5] uses the OPC (Object Linking and Embedding for Process Control) gateway driver, which can operate in a Windows OS system. In this study, the DLS-EtherCAT driver is used. It can support most EtherCAT devices of a general data type. A system architecture, plans and implementation will be presented in this report.

ETHERCAT EPICS ARCHITECTURE

Platform

The platform for EtherCAT application is based on the Linux OS, the real-time patch is optional. Two Ethernet ports are basic configuration, one for control system internet and one to connect to EtherCAT devices. In our applications, CompactPCI (Advantech) [6], MXC industrial PC (Adlinktech) [7], UP Squared (Up-board) [8], Raspberry pi [9], all are acceptable. Some existing control systems for ID control are based on the cPCI platform. As a new platform, we select the MXC platform. UP2 and Raspberry are used for special standalone applications. The x86 or x64 works as the EtherCAT master platform.

IgH EtherCAT Master

The IgH EtherCAT Master is an open-source EtherCAT communication software tool [10] for the Linux platform. The devices in the EtherCAT network can be divided into master and slaves. The master acts as the controller of the entire network and is responsible for sending instant packets to each slave to read data or control its behaviour. The Linux OS kernel version must be 2.6 or 3.x. Currently the version of IgH EtherCAT modules is 1.5.2 which was released on 2013-02-12. The performance was studied by Soyeon Kim [11], which shows that the real-time performance is similar to or better than Beckhoff's TwinCAT. The Ethernet driver is divided into the native EtherCAT-Capable Ethernet drivers and the Linux standard Ethernet driver. Users must use the first driver to support real-time communication. After installation of the IgH EtherCAT master, execution of the command “ethercat version” can check if the machine has the EtherCAT driver module loaded, the command “/etc/init.d/ethercat status” checks the status of the IgH EtherCAT master, and the command “/etc/init.d/ethercat stop(start or restart)” controls the behaviour of the IgH EtherCAT master.

DLS EtherCAT EPICS Support

The Diamond Light Source (DLS) EtherCAT is an EPICS support module to interface an EtherCAT bus to EPICS. It uses a scanner process that serves as a server to communicate with EPICS IOC. The PDO (Process Data Objects) and SDO (Service Data Objects) access are supported. The module along with Diamond's Remote I/O was presented in [3]. An EtherCAT device with “REAL” data type of PDO is not supported. We hope to be able to support it in the future. The DLS EtherCAT support consists of four components:

1. Real-time Linux kernel (Optional)
2. IgH EtherCAT device driver
3. Scanner
4. IOCs.

The EPICS environment with asynDriver (asynchronous driver support) and Sequencer (snc/seq) modules are needed for running the DLS EPICS IOC.

Start-up

After the slaves (EtherCAT devices) are connected to the setup, the EtherCAT command line tool can help to visualize it. First, the platform must find the EtherCAT devices

CONTROL SYSTEM UPGRADE FOR THE FFAG ACCELERATOR COMPLEX AT KURNS

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Abstract

Fixed field alternating gradient (FFAG) accelerator complex has been operated as a proton driver for the experiment of accelerator driven system (ADS) at Institute for Integrated Radiation and Nuclear Science, Kyoto University (KURNS). PLC based control system has been developed and the operator interface has been connected to PLC via network. Originally, a LabVIEW based operational interface was chosen to construct the system because of its easiness. However we met an upgrade problem, and a new control system based on EPICS instead of LabVIEW was introduced in 2010. In the spring of 2018, the replacement from LabVIEW to EPICS has been almost completed except for the beam interlock system and the LINAC control system provided by LINAC production company (AccSys). Also, the EPICS archiving tool (Archiver Appliance) has been invoked and operated at the end of 2017. This presentation reports the details of the current control system and also the upgraded GPIB control and storage system.

INTRODUCTION

FFAG accelerator complex has been operated as a proton driver for the ADS experiment [1]. The construction of this complex had been started since the fiscal year of 2002 and with this complex, the world first ADS experiment was carried out in March, 2009 [2].

The KUNRS complex consists with two ion sources, H$^-$ linac and four FFAG rings. Figure 1 shows the schematic view of KURNS complex.

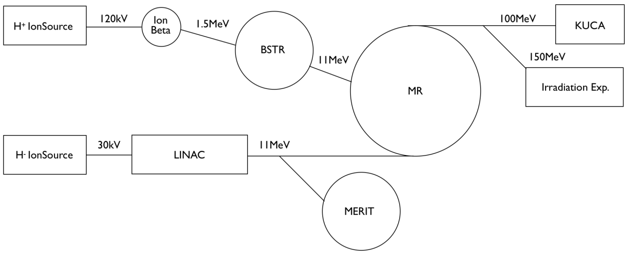

Figure 1: Schematic View of the KURNS Complex.

To control this complex, PLC based control system had been developed. Originally, operator interface had been developed based on a LabVIEW [3]. Since 2010, the aim for the sophistication and stability, we introduced EPICS control system [4]. The immigration from LabVIEW to EPICS had been almost completed in the spring of 2018 except for the beam interlock system and Linac control system.

OVERVIEW OF CONTROL SYSTEM

In the KURNS complex, PLC-based systems have been adopted since the beginning of construction. The operator communicates with the PLC via the network, and the control target device such as the electromagnet power supply is operated by receiving a command from the PLC.

About 20 PLC-CPU modules and 20 Linux PCs, 5 Windows PCs and 2 board computers and 2 servers are used. Also, 20~35 network cameras are used for an equipment monitoring and beam profile observation.

These control devices are connected by an independent network for the accelerator control. Figure 2 shows a diagram of control system.

Since all the devices are connected to the same network, high network load is becoming a problem.

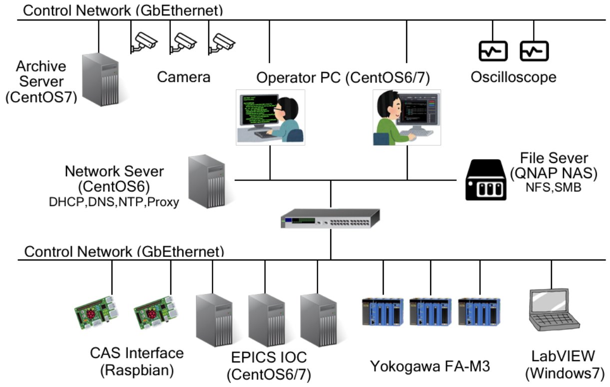

Figure 2: Schematic View of the Control System.

For the device control system, EPICS-based ones and GPIB controlled ones are mixed. EPICS-IOC consists of Yokogawa's PLC FA-M3 and CentOS6 or CentOS7 PC. The number of EPICS-IOC is about 15.

From the point of necessary processing capacity, it is possible to aggregate them into several units. Since accelerator components are often replaced at the KUNRS complex, EPICS IOCs are prepared for each section such as ring and beam line to cope with this. It realizes the flexibility of control system.

RENEWAL OF STORAGE SYSTEM

During the past 10 years, KURNS control system had changed file server three times. One is Linux-based file server and two are mac os based file servers.

Since the period of use was exceeded five years in December 2017, we began to consider updating the file server. Requirements for the new file server are

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VACUUM CONTROL SYSTEM FOR THE TAIWAN PHOTON SOURCE

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Abstract

The Taiwan Photon Source (TPS) is a 3 GeV storage ring. A NI C-RIO controller, basic to the real-time, EPICS program, is used and designed such as to maintain ultra-high vacuum conditions and protect vacuum components. Pressure readings from ionization gauges are taken as the logic signal to control sector gate valves to protect ultra-high vacuum condition. Monitoring of vacuum components, water-cooling systems and chamber temperatures serves to protect vacuum equipment from radiation power. The evolution and status of the control system is presented in this paper.

INTRODUCTION

Commissioning for the TPS, a low-emittance 3-GeV synchrotron ring, started in December 2014 and is now currently operated in top-up mode at 400mA for users. During past year's operation, the design goal of 500mA beam current was archived on December 2015. Until the last machine shut down in June 2018, a total beam dose of 3631 Ah was accumulated and the beam cleaning effect decreased to 1.43×10^{-11} Pa/mA. Table 1 lists some operational milestones of the TPS in past years.

Table 1: Milestones for the TPS Currently in Operation

Date	Milestone
2014.12	first beam stored
2015.03	100mA beam current archived
2015.12	500mA design goal archived
2016.09	open to user (300mA)
2016.11	1000 Ah beam dose accumulated
2017.11	400mA operational Beam Current

The TPS storage and booster rings are located in the same tunnel. The storage ring with a circumference of 518.4m, is divided into 24 sections, including 24 bending and 24 straight sections. Each section corresponds to one control instrument area (CIA). Figure 1 shows a schematic 3D drawing of the TPS vacuum system with the storage ring (SR), booster ring (BR) and control-instrument area (CIA). The vacuum component connection cable lengths between tunnel and CIA are 20 to 30 meter long.

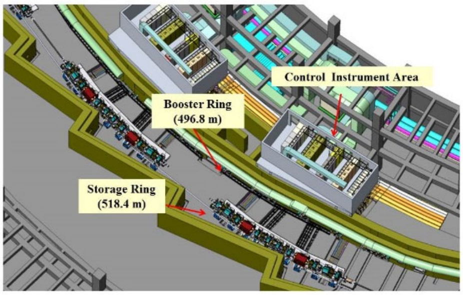

Figure 1: Schematic 3D drawing of the TPS vacuum system.

Figure 2 illustrates the layout for 1/24 of the TPS vacuum system, consisting each of a straight and a bending section with two sector gate valves (SGV), two pumping gate valves (PGV), two front-end valves (FEV), six metal angle valves (MGV), six ionization gauges (IG), ten non-evaporable getter (NEG) pumps, six sputtering ion pumps (IP), and eight turbo-molecular pumps (TMP). The vacuum chambers inside the cell contain two straight ducts S3, S4, and two bending chambers B1, B2; the S1 and S2 ducts are located at both ends of the cell isolated with two SGVs [1].

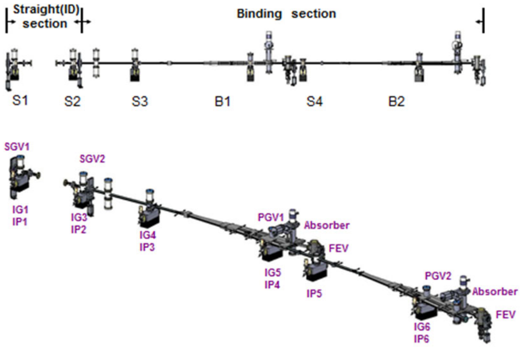

Figure 2: Layout of 1/24 vacuum section.

The mechanism of the vacuum control system is to maintain and protect ultra-high vacuum conditions by controlling and monitoring vacuum components as described above. The safety interlock system is based on the conditions in vacuum components, such as a gauge, ion pump or valve. The following sections describe the design concepts.

VACUUM CONTROL SYSTEM

TPS uses EPICS (Experimental Physics and Industrial Control System) to control and monitor the accelerator machine. EPICS can provide a standard client-server model for a distributed system. In the TPS vacuum control system, a Compact-RIO real-time controller from National Instrument® serves for the vacuum safety interlock, data acquisition and monitoring systems. Between the C-RIO and vacuum system, the interface of I/O communication is used by the I/O connect port of the vacuum controllers , such as vacuum gauges, pumps and meters for cooling water, or directly by the I/O terminals of the vacuum components. The architecture of the control and communications relations is shown in Fig. 3.

RECENT DEVELOPMENT OF THE RIKEN RI BEAM FACTORY CONTROL SYSTEM

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Abstract

We report on the development of the successor to the existing controller devices used for the magnet power supplies in the RIKEN Radioactive Isotope Beam Factory (RIBF). The existing system controlling the magnet power supplies is operated on the Versa Module Europa (VME) computing machines, under the Experimental Physics and Industrial Control System (EPICS) framework. The present controller system has been operated stably for over 10 years. However, it is now commercially unavailable, because the supply of some parts has already ceased. From 2011 to 2016, we have been developing a successor system to achieve essentially the same function as the existing one, but the successor system is designed to run in control systems constructed by programmable logic controller (PLC) modules instead of the VME computing environment, in order to achieve a cost reduction and easily cooperate with other systems.

We set up a test system using this successor and confirmed that a magnet power supply could be controlled in the same manner as the existing system. Now, we plan to begin controlling magnets of beam transport lines using this successor system in the current year.

INTRODUCTION

The RIKEN Radioactive Isotope Beam Factory (RIBF) is a cyclotron-based accelerator facility aiming at the development of nuclear physics, materials, and life science studies. RIBF consists of two heavy-ion linear accelerator injectors and five heavy-ion cyclotrons, including the world's first superconducting ring cyclotron (SRC). Cascades of the cyclotrons can provide the world's most intense RI beams over the whole atomic mass range, using fragmentation or fission of high-energy heavy-ion beams [1]. For example, a 345-MeV/nucleon ^{238}U beam of 70 pnA was successfully extracted from the SRC in 2017. RIBF was constructed as an extension of the old facility commissioned in 1986, by adding three new cyclotrons, and began operation in 2006.

The components of the RIBF accelerator complex, such as the magnet power supplies, beam diagnostic devices, and vacuum systems, are controlled by the Experimental Physics and Industrial Control System (EPICS) [2], with a few exceptions such as the control system dedicated to the radio frequency system of RIBF [3]. However, all the essential operation datasets of EPICS and other control systems are integrated into the EPICS-based control system. In addition, two types of interlock systems that are independent of the accelerator control systems are also operated in the RIBF facility: a radiation safety interlock system for human protection [4] and a beam interlock system (BIS) that protects the hardware of the RIBF accelerator complex from potential damage caused by high-power heavy-ion beams [5].

UPDATE OF CONTROLLER DEVICE FOR MAGNET POWER SUPPLY

Controller Device for Magnet Power Supplies in RIBF

The magnet power supplies are operated both in the old facility section and in the newly added facility section commissioned since 2006 (hereafter, the new facility section). However, there are differences in these controllers according to their introduction times. The magnet power supplies in the old facility section are controlled by our in-house controller device based on Computer-Aided Measurement And Control (CAMAC), a device interface module (DIM) [6]. On the other hand, the magnet power supplies in the new facility section are designed to be controlled by the Network I/O (NIO) system, which is a commercially available control system manufactured by the Hitachi Zosen Corporation. A block diagram of the NIO system is presented in Fig. 1.

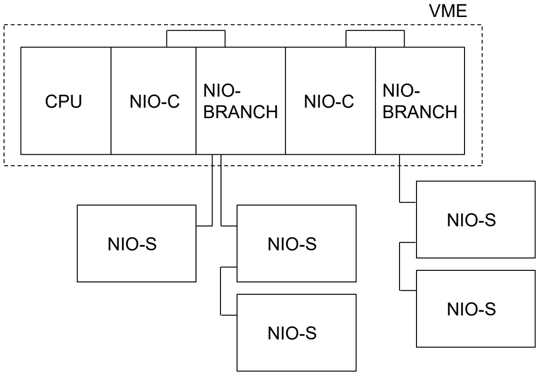

Figure 1: Block diagram of the NIO system under operation.

The NIO system consists of three types of controllers: the NIO-S board, NIO-C board, and branch board. The NIO-S board is a slave board attached directly to the magnet power supply, which controls it according to a signal sent from an upper-level control system through the NIO-C board. The NIO-C board acts as a master board of the NIO-S boards and is designed to operate in the Versa Module Europa (VME) computing machines. The NIO-C board not only has an NIO board, but also an additional board dedicated to High level Data Link

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CMS ECAL DETECTOR CONTROL SYSTEM UPGRADE PLAN FOR THE CERN LARGE HADRON COLLIDER LONG SHUTDOWN II

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Abstract

The Electromagnetic Calorimeter (ECAL) is one of the detectors of the Compact Muon Solenoid (CMS) experiment at the CERN Large Hadron Collider (LHC). The ECAL Detector Control System (DCS) software has been implemented using the WinCC Open Architecture (OA) [1] platform. Modifications that require fundamental changes in the architecture are deployed only during the LHC long shutdowns. The upcoming long shutdown (2019-2020) offers a unique opportunity to perform large software updates to achieve a higher modularity, enabling a faster adaptation to changes in the experiment environment. We present the main activities of the ECAL DCS upgrade plan, covering aspects such as the re-organization of the computing infrastructure, the consolidation of integration tools using virtualized environments and the further usage of centralized resources. CMS software toolkits are evaluated from the point of view of the standardization of important parts of the system, such as the machine protection mechanism and graphical user interfaces. Many of the presented features are currently being developed, serving as precursors to the major ECAL upgrade foreseen for the next long shutdown (~2024-2025).

INTRODUCTION

The CMS Electromagnetic Calorimeter (ECAL) detector is composed of a scintillating crystal calorimeter and a lead/silicon preshower. The CMS experiment takes collisions data at the LHC, requiring extremely high reliability and the minimum down-time of the various detectors. The ECAL detector is subdivided in partitions as follows: Barrel (EB), Endcaps (EE) and Preshower (ES). The EB partition consists of 36 Supermodules (SM) each containing 1700 crystals, the EE consists of two endcaps split in four semi-circles (Dees), each containing 3662 crystals, and the ES consists of two circular structures.

The DCS controls and monitors the status of the hardware of each partition: cooling, powering systems, safety systems, environmental monitoring systems and other external interfaces. The DCS software coordinates the interaction between the different subsystems, providing an effective and meaningful way of operating the detector. From the architectural point of view, the DCS software is built by a hierarchy of components, whose main features can be organized into one of the following categories: Systems Configuration (peripheral addresses, database archivers, alarms, notifications, etc.), Finite State Machine (FSM), Automatic Actions (AA) and User Interfaces (UIs).

The CMS ECAL DCS [2] has successfully supported the ECAL operations since the CMS commissioning, more than 10 years ago. The CMS detectors maintenance is mainly driven by the LHC schedule, often restricted to periods of 2 to 5 days, called Technical Stops (TS). Major modifications are postponed to the Extended Year-end Technical Stops (EYETS) or the LHC Long Shutdowns (LS). The next LS will last for about two years, starting at the end of 2018. During this period, also known as the Second Long Shutdown (LS2), multiple activities across the LHC, Injectors and LHC Experiments will be performed [3]. Following the previous re-integration and consolidation of the CMS ECAL DCS [4], the LS2 provides an ideal opportunity to bring new features into operation, improve the maintainability of the CMS ECAL DCS software and increase the level of availability of the systems.

DCS UPGRADE PLAN OVERVIEW

Multiple activities are scheduled for the LS2; however, this paper focuses on those that imply significant changes to the DCS architecture:

- Re-configuration of the low voltage powering system. The device distribution at the Controller Area Network (CAN) level will be modified to increase the overall performance of the system;
- Extension of the protective automatic actions. The plan includes a proposal to increase the granularity of the current actions, the implementation of new ones and the evaluation of existing frameworks;
- Software standardization. The existing development guidelines will be extended and applied during the creation/modification of every component.
- Consolidation of the CMS ECAL DCS test platform. The usage of CMS automated deployment and testing tools will contribute to have faster development cycles, while reducing the time spend on maintenance;
- Improvements in the Programmable Logic Controller (PLC) based protection and safety systems.

Some of the LS2 activities present dependencies that define the order in which they must be executed (e.g. software updates come after the changes in the hardware layout). The LS2 upgrade plan is organized according to the tasks priority and dependencies (See Fig. 1) and it will be refined in the upcoming months, in order to meet all the requirements presented by the ECAL community.

EXTENDING THE REMOTE CONTROL CAPABILITIES IN THE CMS DETECTOR CONTROL SYSTEM WITH REMOTE PROCEDURE CALL SERVICES

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Abstract

The CMS Detector Control System (DCS) is implemented as a large distributed and redundant system, with applications interacting and sharing data in multiple ways. The CMS XML-RPC is a software toolkit implementing the standard Remote Procedure Call (RPC) protocol, using the Extensible Mark-up Language (XML) and a custom lightweight variant using the JavaScript Object Notation (JSON) to model, encode and expose resources through the Hypertext Transfer Protocol (HTTP). The CMS XML-RPC toolkit complies with the standard specification of the XML-RPC protocol that allows system developers to build collaborative software architectures with self-contained and reusable logic, and with encapsulation of well-defined processes. The implementation of this protocol introduces not only a powerful communication method to operate and exchange data with web-based applications, but also a new programming paradigm to design service-oriented software architectures within the CMS DCS domain. This paper presents details of the CMS XML-RPC implementation in WinCC Open Architecture (OA) Control Language using an object-oriented approach.

INTRODUCTION

CMS DCS applications are implemented using the SIMATIC WinCC OA [1] platform, mostly written in its native programming language called control (CTRL) language. The CTRL language is a C-like language with a very poor type definition syntax, not suitable for programming complex software architectures. The CMSfwClass [2] is a programming framework to build object oriented (OO) applications using CTRL language. The CMS XML-RPC toolkit relies on the CMSfwClass framework, which permits a better implementation of the software architecture after an extensive planning and design phase. The toolkit provides a set of software classes to build client-server architectures (See Fig. 1), enabling heterogeneous software entities to act as service providers (servers) or service requesters (clients).

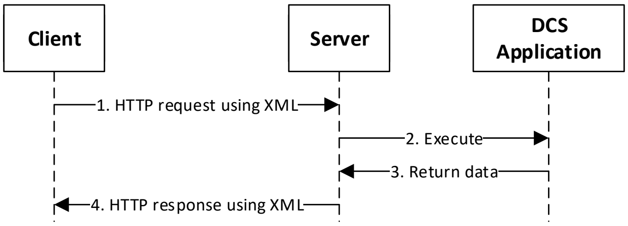

Figure 1: Client-server activity diagram on XML-RPC.

USE CASES

During the design phase, the software models were prepared to support at least the following scenarios: Remote procedure calls from the DCS user interface (UI), service-oriented collaboration between DCS applications, and DCS web services.

Remote Procedure Calls from the UIs

The CMS DCS is a large distributed environment, organized in a hierarchy of nodes and accessed from remote lo-

TINE RELEASE 5.0: A FIRST LOOK

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Abstract

The TINE [1] control system evolved in great part to meet the needs of controlling a large accelerator the size of HERA, where not only the size of the machine and efficient online data display and analysis were determining criteria, but also the seamless integration of many different platforms and programming languages. Although there has been continuous development and improvement during the operation of PETRA, it has now been 10 years since the last major release (version 4). Introducing a new major release necessarily implies a restructuring of the protocol headers and a tacit guarantee that it be compatible with its predecessors, as any logical deployment and upgrade strategy will entail operating in a mixed environment. We report here on the newest features of TINE Release 5.0 and on first experiences in its initial deployment.

INTRODUCTION

Originally a spin-off of the ISOLDE control system [2], TINE is both a mature control system, where a great deal of development has gone into the control system protocol itself, offering a multi-faceted and flexible API with many alternatives for solving data flow problems, and it is a modern control system, capable of being used with both cutting-edge and legacy technology. In addition to publish-subscribe and client-server transactions offered by many other control systems, TINE supports multi-casting and contract coercion [3]. As the TINE kernel is written in straight C and based on Berkeley sockets, it has been ported to most available operating systems. Java TINE, with all of its features, is written entirely in Java (i.e. no Java Native Interface). All other platforms, from .NET to Matlab to LabView to Python, make use of interoperability with the primary TINE kernel library. Furthermore, any client or server application based on TINE and its central services does not require any non-standard or third party software (i.e. there are no LDAP, MySQL, Oracle, Log4j, etc. dependencies).

The transition to TINE Release 4.0 was reported some time ago [4], where numerous features of TINE were enumerated, some of which (e.g. multicasting, redirection, structured data) set it apart from other control systems in common use. In addition, TINE offers a wide variety of features designed for efficient data transport and communication in large systems.

A series of meetings in 2012 identified long-term goals and established a roadmap for the future Release 5.0. Many of these goals have been realized over the past several years, showing up in new minor release versions of TINE, the last being version 4.6.3. What sets Release 5.0 apart and warrants a new major release number are some necessary changes to the protocol headers.

In the following we will identify and discuss those relevant embellishments which have ensued since the 2012 meetings and have culminated in TINE Release 5.0.

RELEASE 4 ISSUES

As noted in the introduction, a general collaboration meeting in 2012 identified certain aspects which needed to be addressed. These include the following.

Protocol Issues

The TINE protocol makes use of Berkeley sockets and TINE Release 4 originally did not properly support IP version 6 (IPv6), as the socket API calls used were all IPv4 centric. Although there is no mad rush to use IPv6, it does offer advantages which could be of interest in the not too distant future.

Header Issues

Several nice-to-have features, which potentially make life easier for administrators tracking connectivity problems, could only be added by expanding the existing protocol headers (and thereby requiring a new major release). For instance the process ID and application type of a connected client are not available under Release 4.

In addition, some supported features required workarounds under some circumstances, which could also only be ironed out by additional information not currently available in the Release 4 protocol headers. For instance, a generic client making a request to a server for a property's canonical data set can ask for the DEFAULT data set (and thus avoid an independent query to obtain the property characteristics). The returned data header will in fact provide the proper data format, but not explicitly give the correct data size. The latter can usually be inferred from the number of data bytes returned. However, if the request in question was truncated by the server, then the property data size which *should* be used in a request is an unknown quantity.

Finally, large data sets often require packet reassembly in the TINE kernel. For example, IPv4 jumbo datagrams can have a maximum length of 64 Kbytes. Any larger data set will require assembling multiple packets. In Release 4, the request and response headers hold the total message size in bytes in an unsigned short, i.e. precisely the 64 Kbytes of an IPv4 jumbo datagram. TINE transfers can of course use a TCP stream, or shared memory, rather than datagrams, but the same packet reassembly exists.

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INJECTION CONTROL OF THE TPS

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Abstract

Injection control application served for Taiwan Photon Source (TPS) to help commissioning and operation of the machine. Top-up injection functionality is available from machine commissioning stage to accelerate vacuum conditioning. During last two years, several updates have been done to enhance flexibility for the injection control. The injection control includes foreground and background processes to coordinate the operation of e-gun, linear accelerator, booster synchrotron, storage ring by the help of event based timing system. Lifetime calculation of the storage ring is also synchronized with the injection process. Detail of the implementation will be presented in this report.

INTRODUCTION

The Taiwan Photon Source TPS [1] is a latest generation of high brightness synchrotron light source which is located at the National Synchrotron Radiation Research Center (NSRRC) in Taiwan. TPS consists of a 150 MeV electron linear accelerator (linac), a 3 GeV booster synchrotron, a 3 GeV storage ring, and experimental beamlines. Ground breaking for civil construction was held on February 2010. The civil construction completed in April 2013. Accelerator system's installation and integration started in later 2013. The control system environment readied in mid-2014 to support subsystem integration and test. After 4 months of hardware/software testing and improving, the commissioning of booster and storage ring was started in December 2014. First synchrotron light shines in the last day of 2014 [2].

Injection control application with top-up functionality was deploy at early period of commissioning phase to release loading of operator and increase beam dosage accumulation to accelerate vacuum conditioning. Constant current with lower and upper limit top-up injection was used for user service since September 2016. However, time interval between injections vary slightly which caused by beam lifetime variation affected by machine conditions such as coupling, nonlinear beam dynamics, insertion device parameters (gap and phase) changed, etc. User could hardly predict the timing of injection even hardware gating signal provided. The experimental data deteriorated by the injection transient. Some beamlines could use hardware gating signal to exclude the transient but most of the instruments and data acquisition systems which cannot gated by hardware gating signal were sensitive to the injection transient. The top-up injection control had been revised to fixed time interval between injections in early 2018. The time of next injection is predictable to suspend data acquisition during the injection window. Maximum stored beam current is set to 405 mA at the moment. The storage ring is refilled every 4 minutes. Beam current drops around 4 mA during this period, it takes about a few seconds (< 5 sec) to refill the stored beam current back to 405 mA.

INJECTION SUPPORT SYSTEM

The injection process need coordinate various subsystem such as electron gun, buncher, RF system of linear accelerator, injection and extraction pulse magnets of the booster synchrotron, and injection septa and injection kickers of the storage ring.

Linac and Booster Synchrotron

The TPS injector consists of a 150 MeV linac and a 3 GeV booster synchrotron. The 150 MeV linac was available for booster injection in the 2nd quarter of 2014. Measured linac beam parameters are well accepted with its specifications. The LTB transfer line has been successfully commissioned with beam and the magnet settings agree with designed expectation [3].

The booster synchrotron was commissioning in the third quarter of 2014 successful. Optimization were done in performance for routine operation. These optimizations consist of system upgrade to improve its weakness and the improvement of the ramping procedure to increase the capture and ramping efficiency of the beam charge, optics characterization [4].

Pulse Magnets and Pulsers

The pulse magnets of TPS consist of one booster injection septum and one booster injection kicker, two booster extraction septa and two booster extraction kickers, two storage ring injection septa and four storage ring injection kickers, and two storage ring pingers for diagnostic purpose [5]. Coordinate operation of these pulse magnets except pingers are necessary for storage ring injection.

Event Based Timing System

Event based timing system was adopted to coordinate operation of TPS include injection. The event system consists of event generator (EVG), event receivers (EVRs) and timing distribution fiber network [6]. Machine clocks (repetition rate, revolution clock of BR and SR, synch clock, etc.) are distributed by distributed bus. While trigger events for the injection are management by the sequence RAM inside of the EVG which installed the timing mater node which is the sources of major timing events. The 125 MHz event rate will deliver 8 nsec coarse timing resolution.

A control page for the EVG configure and testing as shown in Fig. 1, The interface provides a tool to configure event generator such as clock rate, sequence RAM, DBUS,

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THE LENS EFFECT IN THE SECONDARY EMISSION BASED SYSTEMS OF JOINT SEARCHING IN EBW*

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Abstract

The results of the developed scan lines generator for the magnetic correctors system are presented. Get the dependency between various types of scan lines and distribution of the allocated energy in the electron beam welding facility. The lens effect in the secondary emission based system of joint searching, using 3-fragment linear scan line is received. The accuracy of the joint searching system (the error of the positioning system) is 0.05 mm, the lens effect can decrease this value several times. The requirements for the creation full calibrated system of joint searching are listed.

INTRODUCTION

Electron beam technologies based on using beam source (electron gun) with accelerating voltage about some decades kilovolts and power from several watts to several decades kilowatts. The joint search system is very important part of the electron beam welding facility, it allows scan the surface of the target and sees the map of scanning area with asperities of the surface, in particular, the system allows see the joint.

Basically, the principle of functioning the joint search system is reflection and reemission the part of electrons, which interact with the target surface. The back current is measured by the isolated electrode. Different areas of the surface have different reflection coefficient, so we can see the different current values depending on the surface traits. In practice, we need the beam reflecting system with a reading of values from sensors.

EXPERIMENTAL SETUP

The experiments were conducted in the Budker Institute of Nuclear Physics (Siberian Branch of the Russian Academy of Science). The experimental setup has the vacuum chamber, the electron gun (up to 60 kV) with current ability up to 750 mA [1], two-coordinate reflection system based on cos(theta) coils, magnetic amplifiers (bipolar current sources up to 1.5 amperes), electrode, amplifier, and processing block of the joint search system.

Processing block include several channels of digital-analog converter which form the signal for magnetic system, one channel of analog-digital converter, which measure the value from the sensor, FPGA based device for synchronous communication between DAC and ADC, and the single-board computer, which provides the network access for staff of the facility, and realizes the interface to change settings of scanning (by changing internal values in FPGA). Figure 1 shows the main equipment of joint searching system, and interaction point with the rest of facility equipment.

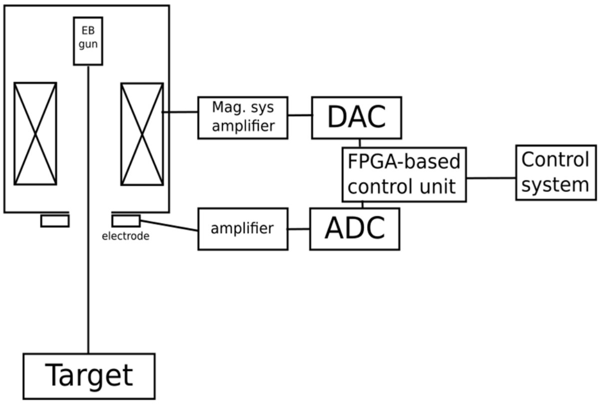

Figure 1: Scheme of the joint searing system.

THE SCANNING PROCEDURE

Despite the scanning system has two coordinates, usually for practice purpose we need only one of them. The beam intersects the joint each period of scanning, and the target movement system moves the detail along the joint. As a result, we can see the position error for all length of the joint. The dual scan uses when we need to get the frame of the scanning area. The experimental setup allows creating this type of scan.

We can illustrate the signal formed by the scanning system. In the simplest case, this signal is sawtooth. Usually, we use a sawtooth-like signal with positive and negative ramps (triangle wave). Using of the one-side sawtooth signal may give us negative effects with quality and appearance of the seam (in the case, when we weld the details with scan), so we use symmetric types of scan.

The scanning system forms the map of the surface, and the size of the map corresponds to the size of the scanning area. We can change the amplitude of the scan, depending on the view, which we want to see. It is possible, to get the ratio between scan amplitude and width of the scanning area. Due to the incline of the beam, the ratio will be changing for each new vertical position of the target. This problem can be solved by using 2 magnetic correctors, one above the other, with the birefringence of the beam. This moment we have the second pair of magnetic correctors but haven't made hardware and software modifications in the control system to get this opportunity. So we fix the distance between the beam gun and target in order to get

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CONTROL SYSTEM USING EPICS TOOLS AT TARLA LINAC

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Abstract

The first accelerator based research facility of Turkey-TARLA is under commissioning at Institute of Accelerator Technologies of Ankara University. It is designed to generate free electron laser and Bremsstrahlung radiation using up to 40 MeV continuous wave (CW) electron beam. The control system of TARLA is based on EPICS and are being tested offline. TARLA also has industrial control systems such as PLC based cryoplant and water cooling system. Its control system is under development, it benefits from the latest version of EPICS framework, i.e. V7. In other words, TARLA control system uses existing demonstrated tools of EPICSV3 as well as pvAccess which comes with EPICSv4 for transferring the large data through control network. Archive (CSS BEAUTY) and alarm (CSS BEAST) system have been set up to detect stability and prevent failures. Operator interfaces have been designed using CSS BOY. Currently, CCDs, PSS (Personel Safety System), MPS (Machine Protection System), Superconductive Cavities, RF Amplifiers, microTCA based LLRF system are being integrated into distributed control system. In this proceeding we summarize the current status and future plans of TARLA control system.

TARLA CONTROL SYSTEM

Control system is one of the main issues. TARLA approach so far was to have sub-systems as independent as possible (including all business logic) with local control system while exposing status read-backs and configuration parameters via TCP/IP interface (slow control only).

TARLA LINAC control will be performed by an EPICS based system operating under the Centos7 operating system on industrial rack mount. EPICS was selected as the main medium due to its commitment to new era accelerators as well as distributed structure of architecture and high performance characteristics. The latest addition to EPICS base, EPICS V4 [1] (EPICS 7 was released in August 2017), was also included in the design goals.

The development environment already used:

- CentOS 7
- EPICS base 3.15
- EPICS V4 4.6
- CSS 4.5.6 (basic)
- MySQL
- Git

Hardware platform for slow control is not finalized. United Electronics hardware platform is being used as IOC for analogue and digital interfaces:

- DNR-6-1G: Compact (3U), 6-slot, rugged, Gigabit Ethernet Data Acquisition and control rack
- UEIPAC 600R: Real-Time, GigE, programmable automation controller (PAC) with 6 I/O slots
- UEPAC 300-1G: Real-Time, GigE, programmable automation controller (PAC) with 6 I/O slots

"In-house" developed TCP/IP based general purposed I/O cards or other custom developed hardware will also be used, while product from other manufactures are also possible.

Standard IOC for devices with TCP/IP interfaces is MOXA DA-682A, x886 2U rackmount computer with 6 gigabit Ethernet ports and 2 PCI expansion slots.

When designing the TARLA Control System, priority and purpose is to create an easy to use/maintain, soft IOC-style, fast, stable and extendable control system suitable for the control and monitoring requirements of all auxiliary systems as well as for laser creation and beam diagnostics.

Architectural Design

Control systems for experimental physics facilities are usually structured in three tiers (see Fig. 1):

User Interfaces. These can be either graphical or non-graphical (command line based) and are usually located in the control room. However, there could be some user interfaces used elsewhere during commissioning and maintenance.

Central Systems and Services. Systems like Timing, Machine and Person safety and computer services that need to run continuously irrespective of user activities, e.g., for archiving acquired data, monitoring alarm states, user authentication services etc.

Equipment Interfaces. This tier is responsible for interaction with equipment and devices. It provides an abstract representation of equipment to higher layers through which the equipment can be monitored and controlled.

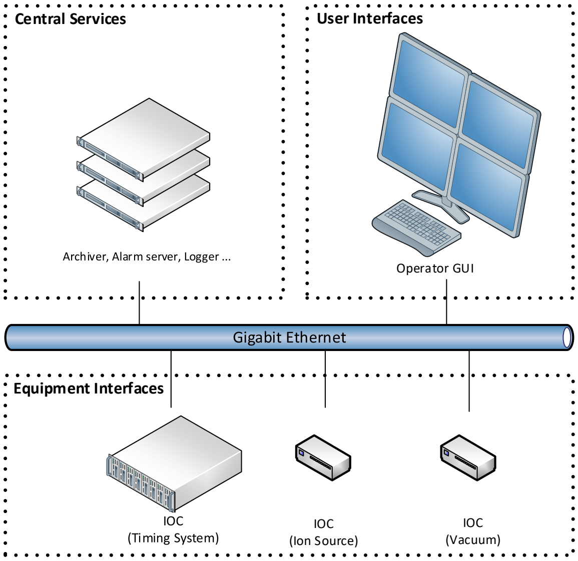

Figure 1: Three tier structure in TARLA control system.

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THE STATE MACHINE BASED AUTOMATIC CONDITIONING APPLICATION FOR PITZ

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Abstract

The Photo Injector Test Facility at DESY in Zeuthen (PITZ) was built to test and to optimize high brightness electron sources for Free-Electron Lasers (FELs). In order to achieve high accelerating gradients and long RF pulse lengths in the normal conducting RF gun cavities, an extensive and safe RF conditioning is required. A State Machine based Automatic Conditioning application (SMAC) was developed to automate the RF conditioning processes, allowing for greater efficiency and performance optimization. The SMAC application has been successfully applied to RF conditioning of several gun cavities at PITZ.

INTRODUCTION

The PITZ [1] has been established to develop, test and optimize sources of high brightness electron beams for FELs like FLASH [2] and the European XFEL [3]. Essential requirements of an electron injector for FELs are the ability to generate a reliable electron beam with a very small transverse emittance (e.g. <1mm-mrad, 1nC bunch charge) and a reasonably small longitudinal emittance. The primary goal at PITZ was to facilitate stable and reliable operation with 60 MV/m accelerating gradient at the photo cathode at 650µs RF pulse length and 10Hz repetition rate. To achieve this, a new RF feed system with two RF windows was installed at PITZ in 2014.

The RF Setup

The gun prototype 4.5 conditioning setup consisting of a 10-MW multi-beam klystron, an upgraded RF waveguide distribution system with SF_6 and Air parts, two 10-MW THALES [4] vacuum RF windows, directional couplers, Ion Getter vacuum Pumps (IGP) and a Pressure Gage (PG), photomultipliers (PMT) and electron detectors (e-det) located around the gun coupler is shown in Figure 1.

The Gun

The PITZ photo electron gun is a 1.6 cell normal conducting L-band cavity, with cathode located at the back wall of the half-cell. The electron beam is generated at the cathode by a laser pulse and then accelerated by RF fields and focused by the solenoid fields.

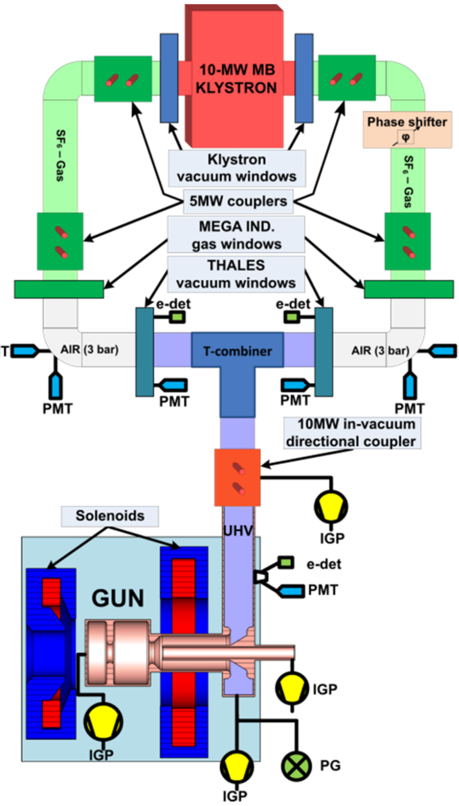

Figure 1: The PITZ RF setup (version 4.5, 2018).

Conditioning

The main goal of the conditioning process is to improve the vacuum in the cavity and the surface condition of the cavity, while applying the RF power is slowly increased in steps up to the operating gradient. During the conditioning process breakdowns may happen with a sharp rise of the pressure in the cavity. In such event the voltage in the cavity is dropped to some initial value and then slowly increased again. The final goal of the gun conditioning is to achieve stable operation at the maximum power level in the gun with solenoid fields.

The State Machine based Automatic Conditioning application (SMAC) was developed to automate the conditioning process for the RF cavities. The application was designed to replicate the operator behaviour during conditioning an RF cavity, allowing for greater efficiency and performance optimization. The interface for the SMAC application has been designed to be user-friendly and intuitive. It provides the user control of the conditioning process and relevant monitoring data.

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EVOLUTION AND CONVERGENCE OF ALARM SYSTEMS IN TANGO

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Abstract

The technology upgrade that represents Tango 9 has triggered the evolution of two of the most used Tango tools, the PANIC Alarm System and the HDB++ Archiving. This paper presents the status of the collaboration between Alba and Elettra Synchrotron sources for the convergence of its both alarms systems under the IEC62682 [1] standard, and the usage of HDB++ tools for logging and diagnostic of alarms. Relevant use cases from the user point of view has been added to the paper as a validation of the benefits of this control system evolution.

INTRODUCTION

Alarms in Control Systems

Alarm Systems have been a common part of control system toolkits for decades. In the Synchrotron community some of the most common tools are PANIC [2] and AlarmHandler [3] for Tango Control System [4], as well as BEAST Alarm System for EPICS.

PANIC and AlarmHandler systems have coexisted within the Tango community for years, but at some point new members of the community asked whether to choose one or the other for their specific domain. This question triggered an effort to compare both systems, extract the best features of them and explore how they could complement each other.

This effort required from us to redefine what an Alarm System was, and what it was expected to do.

What's an Alarm System?

SKA and Elettra institutions proposed to the Tango community to adopt a common terminology and behaviour based on an international norm, the IEC 62682:2014 "Management of Alarm Systems for the Process Industries"[5-6]. The norm states that:

- The primary function of an Alarm System will be to notify abnormal process conditions or equipment malfunctions, and support the operator response.
- The Alarm System is NOT part of the protection nor safety systems, which must have separate tools following its own regulation.
- The Alarm System is part of Operator Response, thus it's part of the HMI (including the non-graphical part of it).

These three statements clarified what our Alarm Systems were expected to do; providing a common ground to start the collaboration on merging both projects.

Alarms within the Tango Control System

It is needed to introduce several concepts on how alarms are developed within a Tango Control System. The following terms describe the object hierarchy:

- Tango Host or Database: the central database where all devices are registered and configuration stored.
- Device Server: Each independent software process distributed across the system, managing one or several Tango devices.
- Device: a Tango Device is an entity that can be typically identified to a hardware piece or software process (e.g. a vacuum pump, a PLC, a motor, a voice synthesizer). Each device exports to the control system its Attributes (process variables), Commands (actions), Properties (for configuration) and States.
- Attributes: Each of the process variables exported by a Tango Device. They support both synchronous or asynchronous reading and writing. At each attribute reading it exports its value, timestamp and quality.
- Attribute Quality: The attribute quality accompanies each value to express the process conditions. Quality can be VALID, INVALID, WARNING or ALARM and it can be set on runtime by a Tango user specifying which ranges of operation/warning/alarm will trigger a quality change.

Quality-based vs Formula-based Alarms

The most primitive scope of Alarm Systems in Tango just included the logging of those attributes qualities in ALARM. But this approach didn't apply when it was required the interaction between multiple devices.

The Tango Alarm System (AlarmHandler device server and its alarm database) was developed [3] to enable logical and arithmetical operations on attribute values, thus extending the alarm triggering from the simple matching of an attribute value within valid ranges.

PANIC [7] was developed by ALBA Synchrotron in 2007 [8] as a Python [9] alternative to the Tango Alarm System. It was based on similar principles but applying a distributed architecture (see Fig. 1) and trying to add annunciator features and more flexibility [10] in alarms declaration, allowing to execute python code for both the formula and the resulting action [11]. This enabled the usage of wildcards for attribute selection, and reusing the data from the alarm evaluation to generate rich-text emails or SMS messaging.

THE DEVELOPMENT OF VACUUM GAUGE MONITORING AND CONTROL SYSTEM USING Web2cToolkit

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Abstract

The Photon Factory is an accelerator-based light source facility that is a part of the High Energy Accelerator Research Organization (KEK) in Japan. At the Photon Factory, a message transferring software named Simple Transmission and Retrieval System (STARS) is used for beamline control. STARS is suitable for small scale remote-control systems using TCP/IP sockets and works with various types of operating systems.

STARS is applicable to various control systems; we developed the vacuum gauge monitoring and control system with STARS in this work.

Web2cToolkit is a framework developed by Deutsches Elektronen Synchrotron (DESY) that provides a user-friendly human machine interface, and developers can easily create web-based graphical user interfaces (GUIs) with Web2cToolkit.

Web2cToolkit supports various types of protocols (e.g., TINE, DOOCS, EPICS, TANGO), including the STARS protocol. We adopt Web2cToolkit as a framework for a front-end GUI application of our vacuum gauge monitoring and control system. Although the application development is still in progress, some features have already been implemented.

OVERVIEW OF STARS

Simple transmission and retrieval system (STARS) [1] is composed of at least one server program "STARS server" and one client program "STARS client". Each STARS client is connected to the STARS server through a unique node name and handles text-based messages through a TCP/IP socket (Fig. 1).

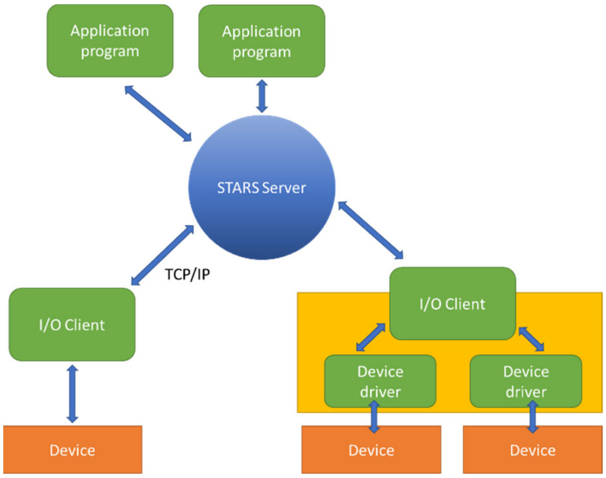

Figure 1: Communication between STARS clients and a STARS server.

The STARS server program is written in Perl. Therefore, it can be executed on different operating systems, such as Windows, MacOS, and Linux. STARS has been introduced as a beamline control system in more than 20 beamlines of the Photon Factory. In addition, an interface program of the beamline interlock systems has been developed using the STARS software.

VACUUM GAUGE CONTROLLER

A large number of vacuum gauges, exceeding 300, are installed in the beamlines at the Photon Factory. These vacuum gauges are connected to various types of controllers that monitor the degree of vacuum of the beamlines. Each controller has a relay output port that either completes or disrupts an electric circuit according to the degree of vacuum, and this port is used for the beamline interlock system. The vacuum environment of the beamlines at the Photon Factory is managed by this beamline interlock system (Fig. 2). The thresholds for these relays can be configured using the switches on the front panels of the controllers or through their respective computer interfaces.

Most of the vacuum controllers have computer interfaces for monitoring the degree of vacuum and operating the controller. Data can be obtained or set through these interfaces and include the following:

- Getting the current value of vacuum;
- Turning the sensor device on or off;
- Setting and Getting the thresholds of the relay output function.

The interface of each vacuum controller has similar functions; however, the different types of communication protocols depend on hardware type or manufacturer.

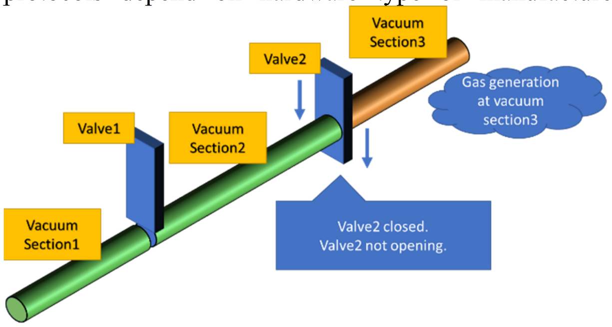

Figure 2: Beamline interlock system and vacuum monitoring.

VACUUM MONITORING SYSTEM

The beamline interlock system uses only the relay output functions; therefore, it is impossible to protect the beamline before a vacuum hazard occurs. The vacuum hazard will interrupt all experiments via leaked synchrotron

DEVELOPMENT OF THE MALFUNCTIONS DETECTION SYSTEM AT VEPP-2000

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Abstract

In 2007, the creation of the electron-positron collider VEPP-2000 (Fig. 1) was completed at the Institute of Nuclear Physics of the SB RAS. The VEPP-2000 collider facility consists of various subsystems, and a failure of any subsystem can lead to the incorrect operation of the complex for several hours or even days. Thus, there is a need to create software that will warn about possible malfunctions. To accomplish the task, software was developed consisting of three modules. The first performs automatic verification of compliance data obtained from the accelerator complex and rules describing the correct subsystems operation. The second module is a user-friendly web interface that displays information about the state of the complex in a convenient way. The third module acts as some intermediary between the first and the second. It processes messages arriving at the message queue and redirects them to all subscribed clients via the web socket. This article is devoted to the development of test software, that is currently running on the VEPP-2000 control panel.

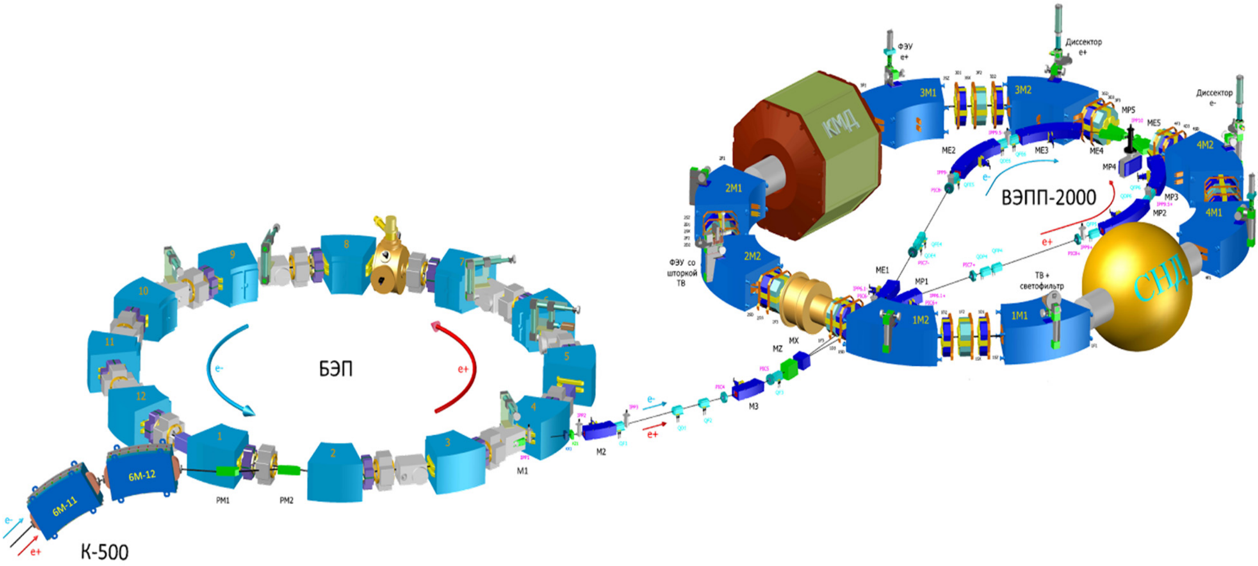

Figure 1: VEPP-2000.

INTRODUCTION

The VEPP 2000 is an electron-positron collider, that was commissioned at the Budker Institute of Nuclear Physics. The VEPP-2000 acceleration complex consists of a few main subsystems: BEP booster ring and VEPP-2000 collider ring. Beam diagnostics is based on 16 optical CCD cameras that register the synchrotron light from either end of the bending magnets and give the full information about beam positions, intensities and profiles. In addition to optical BPMs [1], there are also 4 pick-up stations in the technical straight sections and one current transformer as an absolute current meter. The VEPP-2000 control system [2] has a complex structure and consists of about 4000 channels for monitoring and control. This complicates the timely detection of incorrect operation of the complex or any malfunctions. To solve this problem, software was developed consisting of various parts. The core of the software is a troubleshooting module, that performs automatic validation of rules stored in special configuration files. The following component is responsible for delivering information about the status of the complex to subscribers via the web sockets. Also for the timely notification of new subscribers about the state of the complex uses caching of the state snapshot in the Redis database. Finally, the graphical interface provides a convenient view of all the necessary information.

MODULE FOR CHECKING THE STATE OF THE COMPLEX

The hardware part of the VEPP-2000 accelerator complex has a complicated architecture; therefore, a group system has been developed for the convenience of troubleshooting. Each group is a collection of several channels or

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DEVELOPMENT OF SOFTWARE FOR ACCESSING THE VEPP-2000 COLLIDER FACILITY ARCHIVING SYSTEM

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Abstract

The VEPP-2000 is an electron-positron collider, that was commissioned at Budker Institute of Nuclear Physics. The VEPP-2000 acceleration complex consists of a few main subsystems: BEP booster ring and VEPP-2000 collider ring. Data from accelerator complex are recorded regularly with a frequency at 1 Hz. There is often a need to obtain already stored data for analysis or modeling. In addition, you must provide remote data access to optimize the workflow. The solution of this problem must be universal, and it must be easily adapted to various databases and installation modes. To solve the task, the software was developed based on the client-server architecture. The server part is responsible for processing data in automatic mode according to the developed algorithm. The client part allows to view the data in a user-friendly form. This article talks about the development of software, simplifying access to the VEPP-2000 archiving system, that is launched on the VEPP-2000 control panel.

INTRODUCTION

The VEPP 2000 is an electron-positron collider located at the Budker Institute of Nuclear Physics. The VEPP-2000 acceleration complex (Fig. 1) consists of two main subsystems: the BEP booster ring and the VEPP-2000 collider ring. Beam diagnostics system is based on 16 optical CCD cameras that register the synchrotron light from both ends of the bending magnets and provide full information about beam positions, intensities and profiles. In addition to optical BPMs [1], there are also 4 pick-up stations in the technical straight sections and the one current transformer working as an absolute current meter.

Over than 1200 control channels and 2400 monitoring channels and their joint usage impose rigid restriction on the control system [2]. The architecture of VEPP-2000 software is based on traditional three-layer structure. The important application in the middleware layer is an elaborately designed Log Server [3]. Its purpose is to store all necessary automation system data to the storage.

Every day various accelerator-based experiments are carried out. Sometimes researchers need to obtain the past data for the analysis and calculations. Moreover, it will be useful to have remote access to this data.

Thus, there is the problem of access to the data stored on the hard disk. Also, the solution of this problem have to be universal, and easily adapted to various databases and installation modes.

THE GENERAL SCHEME OF THE APPLICATION

To solve the task, the software has been developed based on the client-server architecture (Fig. 2). HTTP has been chosen as a transport layer protocol, since it is the most common method of data transmission. And also, the REST approach has formed the basis of this application.

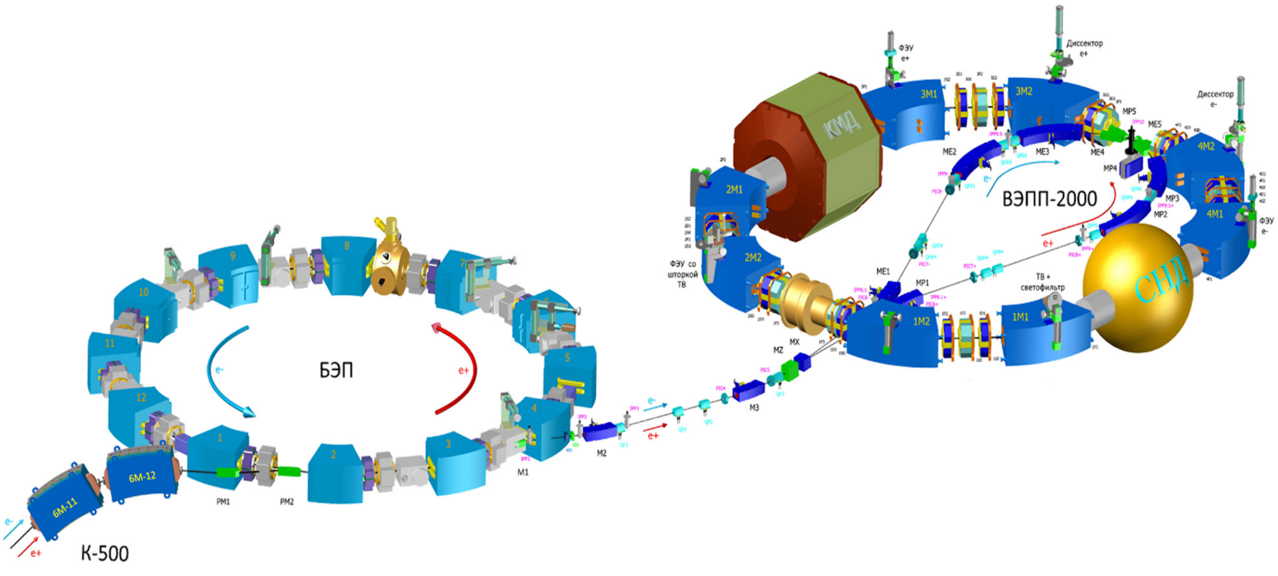

Figure 1: VEPP-2000.

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DESIGN OF RELIABLE CONTROL WITH STAR-TOPOLOGY FIELDBUS COMMUNICATION FOR AN ELECTRON CYCLOTRON RESONANCE ION SOURCE AT RIBF

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Abstract

In the RIKEN Radioactive Isotope Beam Factory (RIBF) project, a superconducting linear accelerator has been implemented to enhance the beam energy necessary for promoting super-heavy element search experiments. A new 28-GHz electron cyclotron resonance ion source (ECRIS) has been installed upstream of it. Its control system has been planned to comprise the Yokogawa FA-M3V series, which is a programmable logic controller (PLC) with Experimental Physics and Industrial Control System (EPICS) because basically the same control system has been successfully operated for our existing ECRIS control system. However, the existing ECRIS control system with PLCs has a disadvantage of low reliability for communications between PLC stations. In addition, higher expandability is required because some devices, such as a power supply for an oven, will be changed depending on ion species produced at the ion source. In the new system, we have designed the control system by utilizing a star-topology fieldbus for communications between the PLC stations to establish safety and expandability.

INTRODUCTION

The RIKEN Radioactive Isotope Beam Factory (RIBF) accelerator facility consists of five cyclotrons, including a superconducting ring cyclotron, and two linear accelerators [1]. In the RIBF, we constructed a distributed control system based on the Experimental Physics and Industrial Control System (EPICS) for electromagnet power supplies, beam diagnostic instruments, vacuum control systems, etc. [2]. In FY2016, we started a new project at RIKEN RIBF to further advance synthesis of super-heavy elements with atomic numbers greater than 119, and the main points are as follows [3]:

A superconducting linear accelerator (SRILAC) is newly installed in the downstream part of the RIKEN linear accelerator (RILAC) to enhance the beam energy [4]. To increase the beam intensity for RILAC, the existing 18-GHz electron cyclotron resonance ion source (ECRIS) [5] is also upgraded to a new superconducting ECRIS (SC-ECRIS) [6].

Of these two, the new SC-ECRIS has the same structure as the RIKEN 28-GHz SC-ECRIS installed in the upstream of RILAC2 [7], which is one of the other injectors of the RIBF currently being operated. Therefore, as the devices to be controlled are almost the same as the RIKEN 28-GHz SC-ECRIS, the new SC-ECRIS control system should be constructed based on the current RIKEN 28-GHz SC-ECRIS control system with several improvements to overcome the limitations of the present system. In this proceeding, we discuss disadvantages of the current RIKEN 28-GHz ECRIS control system and report the design of the newly constructed control system in detail.

RIKEN 28-GHZ SC-ECRIS CONTROL SYSTEM

System Concept

As the main feature of the RIKEN 28-GHz SC-ECRIS control system, Programmable Logic Controllers (PLCs) of the Yokogawa FA-M3 series and EPICS are utilized. The detailed system chart is shown in Fig. 1. The control system is mainly divided into two parts. One is F3RP61-2L, which is a CPU running Linux, to provide the operation services such as controlling of gas valves and power supplies [8]. In the case of the F3RP61-2L-based PLC station, EPICS is installed on the Linux-running system as the PLC CPU's operating system and the EPICS Input/Output Controller (IOC) is implemented as the middle layer for operation services, the so-called embedded EPICS. The other is the part of the implementation of the interlock function as a safety system [9]. Because the sequence CPU-based PLC station has the real-time feature, it is suitable for constructing the safety system, in which not so fast response, such as less than 1 ms, is required. Therefore, the interlock function is realized by the sequence CPU-based PLC station independently from the Linux-CPU-based PLC station, and the state of interlock is monitored by another external EPICS IOC via the TCP/IP network.

As the interlock, the system realizes the function of safely turning off the high-voltage power supply at the time of door opening, turning off the radio frequency (RF) at the time of vacuum abnormality.

Communication between PLC Stations

In the RIKEN 28-GHz SC-ECRIS control system, the main station, which is the installed Linux PLC CPU, manages four substations connected by fieldbus communication electrically isolated by optical fibers. In the case of the Yokogawa FA-M3 series, the fieldbus is called the FA bus. They communicate through FA-bus modules. Because heavy ions generated by an ion source are extracted to the low-energy beam transport by high voltage,

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DESIGN OF PLC TEMPERATURE FLOW ACQUISITION SYSTEM BASED ON EPICS

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Abstract

In the design of the ADS injector II, the RFQ cavity holds a supreme status, and the RFQ temperature and flow information are the key parameters for the cavity frequency tuning. To ensure the long-term, stable and accurate acquisition of temperature flow data is the essential task of control. In this paper, the PLC temperature flow acquisition system which is based on EPICS design was described, and the EPICS driver of this PLC was developed independently. The driver uses TCP/IP connection to EPICS IOC, and the communication protocol uses the "data block overall transmission protocol", to ensure the stability of the device's data communications. After 3 months of long-term operation inspection, this acquisition system can ensure long-term and stable acquisition of real-time temperature and flow data of the equipment, and be able to send control information to related controlled equipment. In addition, redundant PLCs and redundant IOCs were adopted in this acquisition system to make the switch to alternate channels within milliseconds once a channel fails.

TECHNICAL SOLUTIONS AND IMPLEMENTATION

Hardware Components

The water temperature flow monitoring of the RFQ is implemented by two FC 460R controllers which can be backed up each other. The PROFINET protocol is used to connect four sets of PROFINET slaves. The slaves use analog modules to collect temperature and flow signals. The temperature signals are collected by a resistive temperature sensor. The acquisition of flow signal is collected by the rotameter and converted into a current value. The operation schematic diagram of RFQ the temperature flow acquisition system is shown in Fig. 1. The collected signal is transmitted by the analog module from the PROFINET bus to the FC 460R controller. The gathered data is transmitted periodically by the controller to the EPICS IOC, published and archived. If the temperature and flow values exceed the threshold, an alarm message will be transmitted by the controller, and the corresponding action will be executed.

In order to overcome the on-site interference signal, the isolation modules are adopted by the temperature acquisition. In addition, the temperature and flow data are processed by average and anti-shake modes to prevent large fluctuations in data.

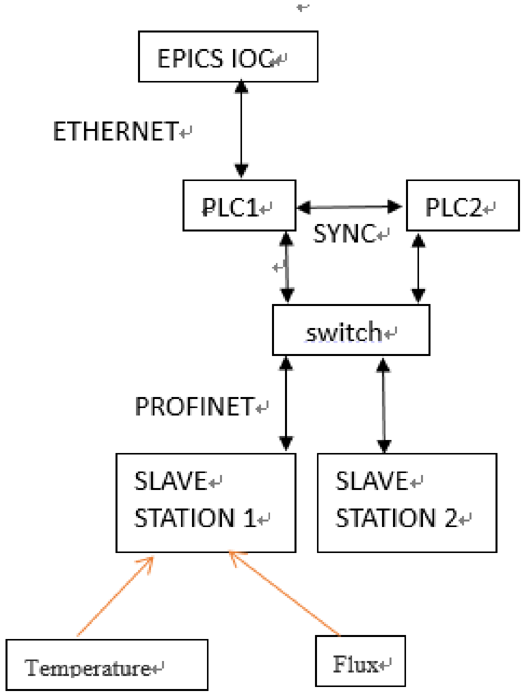

Figure 1: The operation schematic diagram of RFQ the temperature flow acquisition system.

All temperature and flow data are set with threshold comparison. It can be clearly seen through the OPI interface whether the threshold is exceeded. Moreover, the damaged signal of the sensor can be shielded quickly by the ‘bypass’ on the interface without affecting the beam debugging.

IOC Implementation

This driver is used to connect a Phoenix redundant PLC to the EPICS IOC via TCP/IP. A so-called "whole datablock transmission protocol" is used by the communication protocol. This driver is written by the Swiss PSI laboratory for the Siemens S7 PLC based on the basis of the EPICS driver to support redundant PLC pairs.

The data is periodically exchanged between the driver and the PLC through the network, and the size of the data block is fixed. All process variables are arranged in a data block in a certain way, with an offset in the data block as the flag. The process variables could be of all types supported by EPICS. The programmers of IOC and PLC should reach an agreement on the size of the data block and

THE DESIGN AND DEVELOPMENT OF AN AUTO-CONDITIONING SRF CAVITIES SOFTWARE

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Abstract

As one of the major components of ADS Injector II, SRF (Superconducting Radio Frequency) cavities are used to transmit the intense-beam proton reliably, stably and efficiently. Before starting the process of transmitting particle beams, SRF cavities are routinely conditioned to achieve its optimized status in the deliverable energy. The whole conditioning process is involved in various types of hardware devices and is also a heavy task for engineers to manually operate these equipment. In this paper, the software ANSC is presented in details, which is used to automatically condition SRF cavities. At the present, ANSC is in the stage of testing. During the testing, ANSC indeed can achieve comparative results compared with manually operated conditioning.

INTRODUCTION

As China Accelerator Driven System (C-ADS) Injector II achieved the expected target of 25 MeV[1], how to make an improvement in efficiency is our current focus[2]. In every accelerator physics experiment[3], engineers of SRF are always required to condition SRF cavities by manual operation to ensure that these cavities can reach their optimal deliverable energy. The task is heavy for the engineers and manual operation is also low in efficiency. In order to get rid of the difficult situation, our engineers in the ADS control group are developing an Auto-Conditioning SRF Cavities program called ANSC. Currently, ANSC is in the stage of testing and obtained some positive feedback during the testing process. ANSC is based on the distributed control system EPICS, which has been widely used in accelerator field. Therefore, it is totally compatible with current control system in ADS and is also convenient to update the software in the future. During the development of the program, python and Epics Qt are core components in which Epics Qt is used to customize GUI and python is exploited to carry out the auto-conditioning process.

In the following sections, ANSC will be described in detail.

THE GUI OF ANSC

Because of flexibility and practicality of Qt,it is widely used in software development. At the same time, Epics Qt combines Qt's advantages with EPICS'. As a consequence, it is chosen as GUI design tool of ANSC. In reality, Epics Qt demonstrates its high performance in displaying PVs by Channel Access.

In ANSC, there are two main user interfaces: setting GUI and operation GUI. Setting GUI in Fig. 1 is responsible for setting some basic parameters; Operation GUI in Fig. 2 is used as setting auto-conditioning related parameters and an entry for executing auto-conditioning process.

In the Setting GUI, the key status information is set such as vacuum fluctuation, vacuum protection status and MPS (Machine Protection System), which is key for engineers to execute the auto-conditioning process. Operation GUI is used before the beginning of the process. Its main function is to set important parameters and thresholds such as vacuum thresholds, auto-conditioning up steps and down steps, then start the auto-conditioning process. In addition, scanning frequency and phase can be executed.

Figure 1: Setting GUI of ANSC.

Figure 2: Operation GUI of ANSC.

REALIZATION OF AUTO-CONDITIONING PROCESS

The function of the GUIs is totally carried out by Python. Taking the complexity of auto-conditioning SRF cavities and restriction requirement in time into account, the program consists of four threads, including auto-loading thread, protection thread, exception dealing thread and main thread. The auto-loading thread takes charge of

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INTRODUCTION OF CiADS CONTROL SYSTEM

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Abstract

CiADS is a science researching facility, which destination is about energy Providence. The control system of CiADS will have more than hundred types of device, and include more than thousand equipment and sensors. Based on the background of researching and energy project, the control system should overcome two challenges. First is that building a open architecture to face the flexibility of changed requirement. the second is that the flexibility should as less as possible influence the checking result of nuclear law and standard by authority. To meet the requirement, the control system will be divided into 3 levels. Level 2 will provide the OPI, data analysis interface and simulation to all users. Level 1 provides implement of control and security logic. Meantime it will provide an engine and interface for collection and package of some reconstructed data. Level 0 will implement the local control and provide all data and information to other levels. The paper mainly introduces the architecture and some works to build the control system to make it to overcome the two challenges.

BACKGROUND

CiADS (China Initiative Accelerator Driven System) is a large scientific project. It consists of three parts: linear accelerator, spallation target and nuclear reactor. The facility is a complex system, that consists tens of thousands equipment. There are millions of status information, thousands of control points and automated or semi-automated control processes in the control system. As planned. The control system was completed and put into operation in 7 years.

THE ANALYSIS OF REQUIREMENT

As a normal control system, the requirement of CiADS can be divided into two levels. The basic requirements: real-time acquisition of all state information of facility and can remote control various devices. On this basis requirement, it is necessary to provide enough safety and reliability. In addition, the facility will work at complex and various operation modes, the control system needs to adapt and support it. Finally, the control system also needs to provide data and data analysis support to help the operators to achieve the research aims. The following is explained separately.

Basic Functional Requirements

In order to support the operation of the device, the control system needs to implement remote control and reading status information of all devices., which is the most basic functional requirement of the control system. In such a complex system, there are hundreds of different types of devices, which have different control parameters and different operational functions. To reduce the difficulty of system integration, the unified hardware and software interface should be adapted.

In addition, the timing system must be provided for synchronized device operations; the MPS system for protecting the accelerator and the security protection system for nuclear safety. These together constitute the most basic service of the control system.

The timing system. 1. Provide the Trigger signal to synchronize the output or action of the related equipment. 2. Provide time service to the entire facility to achieve strict synchronization of system time to the relevant device, so that the data or status collected by the relevant device can be analyzed and compared on the same time axis. The CiADS control system will use the White Rabbit technology to implement the timing system.

The beam of proton accelerator will be reached mA, and the energy is hundreds of MeV. In this case, a small loss of the beam will cause serious damage to the accelerator, so a machine protection is necessary. The Machine Protection System (MPS) provides the safety to accelerator, while not affecting the availability. How to balance the safety and availability is a challenging task.

As a nuclear-related facility, the control system also needs to equip a high-reliable safety protection system. This protection system is designed on the analysis of all possible nuclear safety accidents which mainly based on hardware system implementation is based on the facility [1]. The device also requires approval of the nuclear safety regulatory agency.

Operation Modes

During the installation, commissioning (step-by-step debugging) and operation, the entire device will face different operating modes [2]. These different modes will involve the parameters of the device, the protection threshold, and the configuration of the protection system and the operating authority. In order to meet the modes of the facility, the databases, device drivers, and applications

THE CONTROL SYSTEM BASED ON EPICS FOR THE EXPERIMENTAL TARGET PROTOTYPE

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Abstract

Building a high power spallation target is one of the critical issues in Accelerator Driven System (ADS). The control system which was built based on the real-time distributed control software of experimental physics and industrial control system (EPICS) was attempted for the experimental target prototype. There are several sub-systems in the target system, e.g. the elevating system, the vacuum system, the heat-exchanging system. As an IOC, each subsystem was finally integrated into the control system of the target by different drivers and methods because different hardware devices were used for each sub-system. The "SLS s7 driver" which was developed based on the Ethernet Interface was used for the communication between the Siemens PLCs and the Human Machine Interface (HMI). The interfaces between Labview and EPICS were used for the National Instruments (NI) DAQs systems. In addition, the driver developed by ourselves was used for devices with serial ports, e.g. RS-232 or RS-485/422. The control system was finally proved stable and could basically meet the elementary requirements of the spallation target system.

INTRODUCTION

In an Accelerator Driven System (ADS), a heavy metal spallation target locates at the centre of a sub-critical core. A beam of high intensity protons emitted from an accelerator bombard on the target, generating neutrons to drive the sub-critical reactor. Building a high power spallation target is one of the critical issues in an ADS [1]. In China initiative Accelerator Driven System (CiADS), a new concept for a high-power spallation target: the gravity-driven dense granular target (DGT) was proposed.

An experimental target prototype has been constructed and tested for some important issues. The layout of the prototype is shown as Fig.1. The helium loop which is an auxiliary system is separate and not shown in Fig.1. Three loops: Loop 1, Loop2 and Loop 3, as shown in Fig.1, were designed for different functions and experiments. The target design is one of the challenging and key technologies. So, the Loop 1 was designed mainly for testing the performance of the spallation target. At the same time, the feasibility of the mass flow-meters and sieve sorter was also tested. The Loop 2 was designed for testing the feasibility of the heat-exchanger. A proton beam was not considered at the first stage of the target design, so, a middle frequency heating device was used in the Loop 2 to heat the grains before they flow into the heat-exchanger. The Loop 3 acts only as a recovery system. A four-way valve was fixed at the entries of the three loops to control which loop to be used for experiment. Many important issues would be tested and studied as the experimental target prototype running, e.g. flowing character of the grains in the target container, heat conductivity of the grains, the feasibility of the method which is used for measuring the rate of the flow.

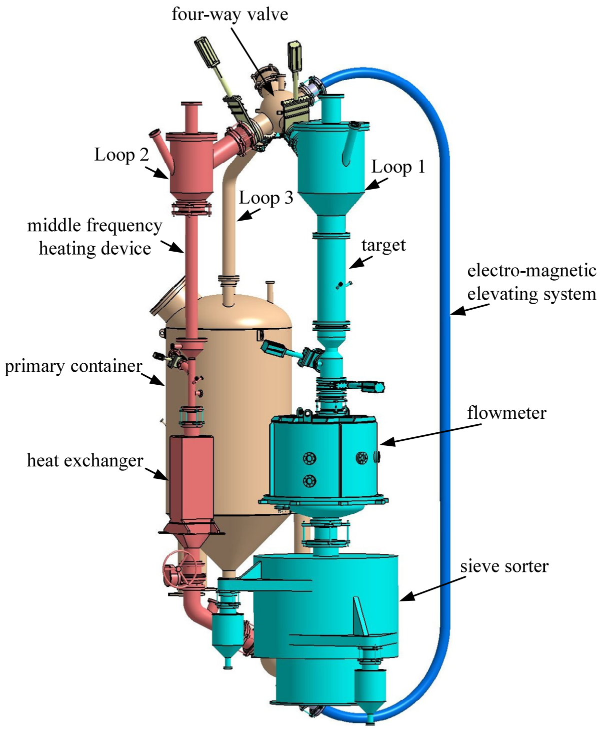

Figure 1: Layout of the prototype.

The architecture of the control system is also one of the important issues to be tested and studied. The control system of the accelerator has been designed and constructed based on EPICS [2, 3]. It will be easy to couple together if the control system of the target system is also constructed based on EPICS. However, considering the software toolkits of EPICS is open-source, the stability of the control system constructed based on EPICS is the most worried and concerned problem due to the extreme high safety requirements of the target system. Constructing the control system based on EPICS for the target system aimed to initially testify the stability of it.

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QUEST FOR THE NEW STANDARD PSI IOC PLATFORM

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Abstract

With its four accelerator facilities the Paul Scherrer Institut (PSI) has already several decades of control system Input Output Computer (IOC) experience. The technology is moving forward fast. The older hardware is becoming obsolete: it is slow, consumes too much power, does not match new computing, networking and bus technologies, and replacements can no longer be purchased as models have been discontinued. All this forces us to opt for a new "standard" IOC platform with increasing regularity. What used to be twenty years, became ten, and is now tending towards five years. Here we present past and possible future IOC platforms which we are investigating. Feedback from the conference would be highly appreciated.

PSI ACCELERATOR FACILITIES

The Paul Scherrer Institut (PSI) operates four accelerator facilities. The oldest of these, the High Intensity Proton Accelerator (HIPA) has already been in operation for more than four decades. It has undergone several beam intensity, hardware and software upgrade and rejuvenation processes. The second oldest, Swiss Light Source (SLS) has been operated for almost two decades and is going to be upgraded to SLS2 soon. Third, the Proton Scanning (PROSCAN) medical cancer-treatment facility, with its superconducting, compact, medical cyclotron (COMET) has been successfully treating patients for a decade, and has recently been extended with the third Gantry area. And the newest, Swiss Free Electron Laser (SwissFEL) is just coming in operation.

Although that was not the case in the past, nowadays all facilities are based on the same or similar hardware. There is a common VME bus system in use, with mostly MVME5100 VxWorks and IFC1210 RTLinux [1] Input Output Computers (IOCs). The common control system is EPICS.

MOTIVATION

Our existing processing platforms are getting gradually old and we also have to respond to availability and performance issues. For some of the used components manufacturers have already issued the end of life notices. Some CPU applications are already at the limits of their resource usage, like processing power and memory and bus throughput and the FPGA applications are exceeding available size.

All, especially older, facilities are constantly going through hardware rejuvenation, due to the lack of the spare parts, being upgraded to match higher processing and precision demands, or are simply been extended or adapted to the new user demands.

Probably the biggest demand is driven by the SLS2 upgrade. This should start in year 2020, and the New Processing Platform (NPP) should provide a solution until then.

The NPP project was therefore initiated in December 2017, and the working group began investigating use cases and possible implementations.

GOAL

The design and implementation of the NPP is seen as the necessity, and it has to provide the platform that can commonly be used in all facilities and should equally serve as base in all application areas. Because it is hardly possible and meaningful to use single identical platform for all use cases, it is desirable to provide for scalable solution. Direct consequence of the common platform is optimal usage of available resources. Sharing the manpower, know-how, development tools and expertise between different groups can greatly speed up our work and lower the costs.

USED PLATFORMS HISTORY

HIPA has initially been based on Digital Equipment's PDP-11 and later on hprt743 single board VME computers with HP-RT OS, but they have been replaced, since around year 2000, with MVME5100 on LynxOS. Custom home-made control system was used.

PROSCAN has always been running on MVME5100, initially on LynxOS, with custom home-made control system, same as HIPA.

HIPA and PROSCAN control systems have then been replaced with VxWorks running EPICS [2] as control system, in scope of control system standardisation project at PSI.

SLS is running EPICS since beginning, initially on MVME2300 VME computers. Later MVME5100 were added, and for a few demanding applications MVME6100, too.

For SwissFEL, new platform has been chosen. In cooperation with Swiss company IOxOS [3], the IFC1210 was introduced. Decision was to keep the VME bus, and new was that two FMC cards could be plugged in, and user code could be implemented in on-board FPGA. For many applications FPGA app using one or two FMC modules was enough, and VME bus was only used to supply electrical power.

At the same time it was decided to go for PREEMPT_RT patched Linux (RTLinux) as the operating system, and EPICS is still our control system.

Now the time has come for a new platform.

REQUIREMENTS

As with any other technology, the time comes to upgrade processing platform to the higher level. Several

DEVELOPMENT OF MicroTCA-BASED LOW-LEVEL RADIO FREQUENCY CONTROL SYSTEMS FOR CERL AND STF

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Abstract

Low-level radio frequency (LLRF) control systems based on µTCA standard have been developed for facilities such as compact energy recovery linac (cERL) and superconducting test facility (STF) at the High Energy Accelerator Research Organization (KEK), Japan. Three different types of boards were developed according to their different applications. Experimental physics and industrial control system (EPICS) was selected as the data communication system for all of these µTCA boards. The LLRF systems showed good performance during the beam commissioning. This paper presents the current status of the µTCA-based LLRF systems in the cERL and STF.

INTRODUCTION

The compact energy recovery linac (cERL) and the superconducting test facility (STF) are test facilities for the 3-GeV ERL and international linear collider (ILC), respectively, constructed at the High Energy Accelerator Research Organization (KEK), Japan [1, 2]. The cERL is a 1.3-GHz superconducting radio frequency (SCRF) machine that is operated in the continuous-wave mode. The STF (and ILC) is also a 1.3-GHz SCRF facility but it is operated in the pulse mode. In order to fulfil the desired beam quality requirements, the radio frequency (RF) field in the RF cavity of each accelerator needs to be controlled precisely. For cERL, the amplitude fluctuation of the RF field should be maintained at less than 0.1% (rms) and the phase fluctuation at 0.1° (rms). The STF (or the ILC) requires RF stabilities of 0.07% (RMS) and 0.35° (RMS) with regard to the amplitude and phase, respectively. Field-programmable gate array (FPGA)-based digital low level radio frequency (LLRF) feedback (FB) systems have been applied to stabilize the RF field [3]. The digital platform for the LLRF systems was realized based on the micro telecom computing architecture (µTCA) standard. We have developed three types of µTCA board according to their applications.

In this paper, we first introduce the digital LLRF system, and then we present the various µTCA boards applied in the cERL and STF. Finally, we present the performance of the µTCA-based digital LLRF systems during beam commissioning.

LLRF SYSTEM

Figure 1 shows the block diagram of a typical LLRF system [3]. The RF pick-up signals from all the cavities are down-converted to intermediate frequency (IF) signals. The IF signals are sampled in the next stage and fed to a µTCA FPGA to execute the DSP algorithms. The baseband in the phase and quadrature components (I/Q) are extracted from the IF signal by digital IQ detection algorithm. The I/Q signals are fed to a rotation matrix to compensate the loop phase. The vector-sum signal is then obtained by calculating the superposition of all the cavity pick-up signals. After being filtered by digital low-pass filters, the I/Q components are compared with the set-values and the I/Q errors are calculated. Then, the I/Q errors are regulated by a proportional and integral (PI) FB controller. The regulated I/Q signals are added to the feedforward (FF) models. The combined signals are fed to the I/Q modulator by a digital to analog converter (DAC) to modulate the RF signal from the master oscillator. Finally, the LLRF FB loop is closed by means of a high-power source, which drives the cavities.

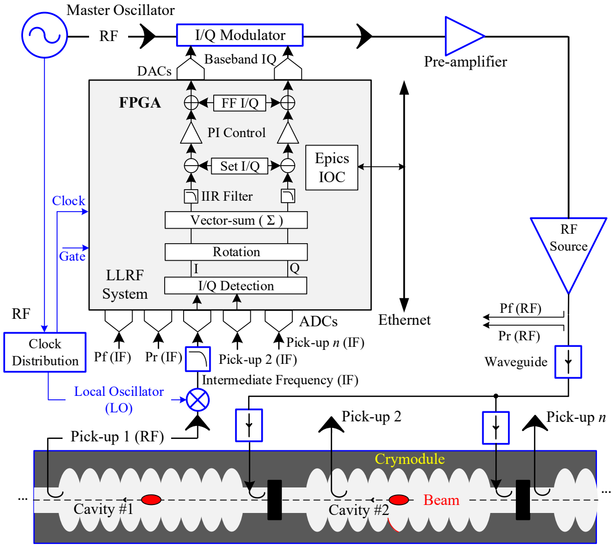

Figure 1: Block diagram of the LLRF system.

µTCA FPGA BOARD

The µTCA FPGA board is the key component of the LLRF system. As shown in Fig. 2, the board integrates ADCs, DACs, an FPGA embedded with power PC (PPC), a digital I/O, and an external trigger. The cavity pick-up signal, forward signal (Pf), reflected signal (Pr), and the reference signal are sampled by the ADCs and fed to the FPGA. The DSP algorithms for the LLRF FB control (see Fig. 1) are implemented in the FPGA. A Linux operation system is installed in the PPC (or ARM). Experimental physics and industrial control system (EPICS) is adopted as the communication protocol. The detailed information about this µTCA board can be found in [4].

A FEEDBACK/FEEDFORWARD SYSTEM AT THE TPS AND ITS COMPONENT PERFORMANCE

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Abstract

For a low-emittance photon light source like the Taiwan Photon Source (TPS), beam stability is a very important property for high-quality photon beams. It is, however, hard to completely remove beam disturbing effects. Therefore, a feedback/feedforward system becomes an effective tool to suppress beam motion. In this report, we discuss the performance of such a system implemented at the TPS. The component performance of the feedback system has been tested to understand its bandwidth limitations.

INTRODUCTION

The Taiwan Photon Source (TPS) is a third-generation light source at the NSRRC with 24 double-bend achromatic cells and a beam emittance of 1.6 nm-rad [1]. To achieve a high-quality beam, the beam motion must be controlled to within 10 % of the beam size or less. The vertical beam size in the center of the straight sections is around 5 µm making it necessary to control the beam motion to better than 0.5 µm.

There are many sources which may adversely affect beam stability[2]. Much effort have been spent to remove or eliminate such perturbations [3]. However, it is hard to remove all kinds of adverse effects. Therefore, a feedback/feedforward system has been developed to counteract beam motions. At first, the components of the feedback/feedforward system are introduced in this paper. The performance and computation model are described in the second part. Third, the performance of the feedback components are discussed and the bandwidth limitations of the fast orbit feedback system is determined.

FAST ORBIT FEEDBACK SYSTEM

There are 24 cells in the storage ring of the TPS, each including seven beam position monitors (BPMs), seven slow correctors and four fast correctors in each cell [4] as shown in Fig 1. The kick angle for the fast horizontal/vertical corrector is 4.8/12 µrad/A, respectively. There are mainly two types of BPMs installed in the storage ring. The k_x/k_y of standard BPMs, which are installed in the arc sections are 13.8/12.73 mm whereas the k_x/k_y of the primary BPMs, installed in the straight sections, are 6.58/8.89 mm. The eight (4 horizontal + 4 vertical) fast corrector power supplies in each cell are controlled by one corrector power supply controller (CPSC).

Libera brilliance+ is used as the BPM electronics. Each BPM platform deals with signal processing of four BPMs resulting in two platforms per cell. The electronics includes custom-written applications with VirtexTM 5 and Virtex 6 to be used for orbit feedback computations. One platform is responsible for the four horizontal correctors per cell and the second platform for the four vertical correctors. The correction rate is 10 kHz and the platform infrastructure is shown in Fig. 2. The bandwidth of the FOFB, shown in Fig. 3, is around 300 Hz in both the horizontal and vertical plane [5].

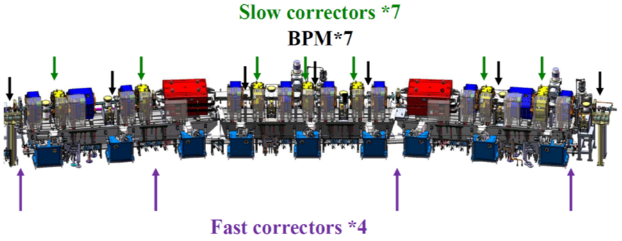

Figure 1: The location of beam position monitors (BPMs), slow and fast correctors in each cell.

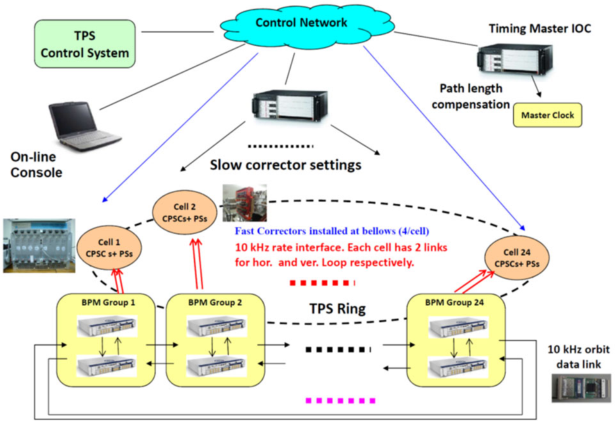

Figure 2: The infrastructure of the fast orbit feedback system.

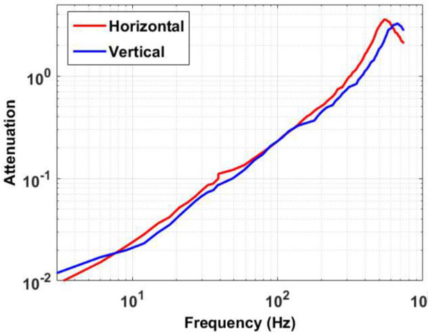

Figure 3: Frequency response of the fast orbit feedback system.

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DEVELOPMENT OF A NETWORK-BASED TIMING AND TAG INFORMATION DISTRIBUTION SYSTEM FOR SYNCHROTRON RADIATION EXPERIMENTS AT SPring-8

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Abstract

Time-resolved measurements in synchrotron radiation experiments require an RF clock synchronized with a storage ring accelerator and a fundamental revolution frequency (zero address) signal. For using these signals around the experimental station, long RF cables from the accelerator timing station, divider modules, and delay modules must be deployed. These installations are costly and require significant effort to adjust the timing by experts. To lower these costs and efforts, the revolution frequency, which is ~209 kHz at the SPring-8 storage ring, and tag information distribution system have been studied based on a high-precision time synchronization technology over a network. In this study, the White Rabbit technology is adopted. The proof of concept consists of a master PC, a slave PC, and two WR switches. The master PC detects the zero-address signal and distributes time stamps with tag information to the slave PC. Then the slave PC generates ~209 kHz signals synchronized with the target bunch by adding the offset time calculated by software. The output signals from the slave PC achieved a measured one-sigma jitter of less than 100 ps.

INTRODUCTION

High-precision timing signals synchronized with a storage ring accelerator are indispensable for time-resolved measurements in synchrotron radiation experiments utilizing short pulse characteristics of the synchrotron radiation. These timing signals have been introduced into the required beamline by deploying long distance RF cables from the accelerator timing station. In this method, beamlines that can utilize the precise timing signals are quite restricted, as their expansion is difficult. Furthermore, introducing these RF signals demands high cost and effort since various types of electronics have to be deployed and adjusted to divide the frequency or to tune the phase.

In order to optimize experimental results, it is quite common to pursue a more appropriate timing distribution system with higher expandability. In other words, distribution of the timing signal should be processed as universal digital information closely coupled with a control system, instead of effecting direct distribution of the analog RF signal. For any beamline that requires precise timing signals, experimental users should be able to employ and manipulate these signals easily by means of GUI programs in a control system.

I have studied a timing distribution system based on a high-precision time synchronization technology over a standard network. Since the system delivers "digital information" related to timing signals over the network, the system can be handled and expanded without difficulty. The timing signal generated based on this information can be precisely and easily adjusted by the software. In addition, other useful information can be attached easily such as a shot number.

As a high-precision time synchronization technology, I have adopted White Rabbit (WR) [1], which is promoted as an international collaborative project. It extends the IEEE 1588 standard and achieves highly precise synchronization with sub-nanosecond accuracy by using clock synchronization at the hardware layer of Synchronous Ethernet and phase detection based on digital dual-mixer time difference. The WR technology is opened to the public at the Open Hardware Repository (OHR) [2], and any information required for development is freely available in accordance with open licenses such as the CERN Open Hardware License [3].

To conform the digital-based timing distribution system, I have built the proof of concept (PoC) system with the minimum configuration. In the case of SPring-8, the aim of the PoC system is to realize generation of a 208.8 kHz revolution frequency signal synchronized with the target bunch of the storage ring, which was accelerated by 508.58 MHz RF, and deliver tag information, such as a shot number.

BUILDING THE POC SYSTEM

The PoC system has been constructed as the first step for verification of the new timing and tag information distribution system, as shown in Fig. 1. The system consisted of a master PC, a slave PC, two WR switches (WR-A and WR-B), a GPS receiver, and single mode fibers (SMFs).

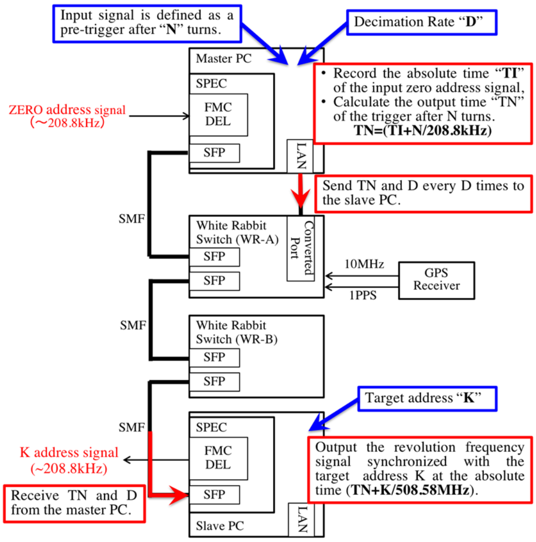

Figure 1: A block diagram of the PoC system.

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RETHINKING PLCs: INDUSTRIAL ETHERNET FOR LARGE-SCALE REAL-TIME DISTRIBUTED CONTROL APPLICATIONS

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Abstract

Many research facilities rely on PLCs to automate large slow systems like vacuum or HVAC, where price, availability and reliability matter. The dominant architecture consists of local units of controllers/modules (programmed in IEC61131-3 languages), which operate mostly autonomously from a SCADA layer.

While some vendors provide low-level stacks to encourage growth of their ecosystems, PLC programming remains largely within a closed, proprietary world.

In this paper, we introduce a different way of thinking about PLC hardware.

Working with the open stacks intended for the design of new EtherCAT (Beckhoff)/Powerlink (B&R) modules, we built an abstract C++- API to control the existing ones. These industrial Ethernet busses can be propagated using standard network hardware, so any RT-Linux system can now control any PLC module from anywhere in our facility using high-level languages (C++, LabVIEW).

This way, PLC modules are seamlessly integrated into our distributed TANGO-based control system. PC-PLC interfaces are no longer needed; or in the case of traditionally implemented subsystems, trivial.

BACKGROUND

Programmable logic controllers (PLCs) are cheap, reliable, modular and fault-tolerant "hard" real time control solutions, even in challenging environments. They are easy to program and maintain, and allow online modification of hardware/software.

With a few notable exceptions [1], most facilities rely on a standard architecture shown in Figure 1: Local units (processors and modules) are distributed in the field, and operate almost autonomously from a SCADA layer, interacting using thin communication links (Profibus, Modbus, OPC, custom serial/Ethernet interfaces, . . .).

This approach has a number of disadvantages:

- It requires control system engineers with skillsets that are not commonly taught together (IEC61131-3 languages for the PLCs vs. high-level languages for the SCADA systems).

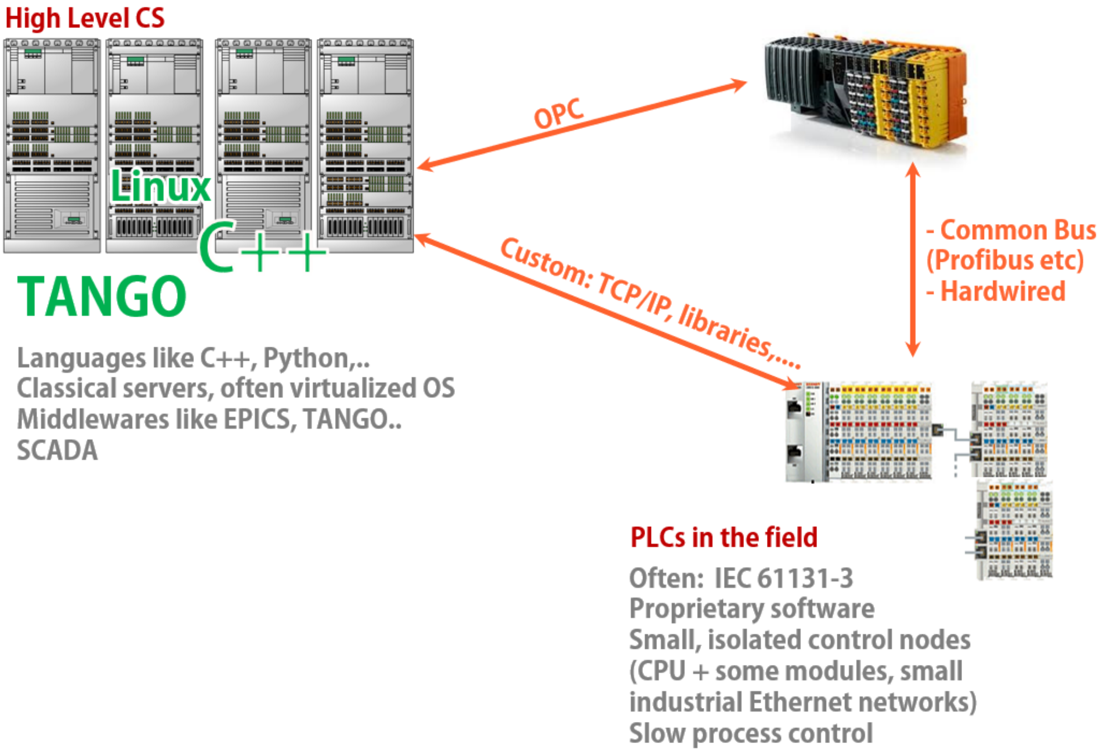

Figure 1: Commonly found PLC architectures.

ACOP.NET: NOT JUST ANOTHER GUI BUILDER

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Abstract

ACOP (Advanced Component Oriented Programming) tools have been useful in control system GUI application development for some time, originally as an ActiveX component [1] offering a transport layer and a multi-faceted chart and then later as a suite of components in the Java world [2]. We now present a set of ACOP components for development in .NET. And where the emphasis in the past has been primarily on rapid application development of rich clients, this new palette of components is designed both for fully featured rich-client development in any of the .NET supported languages (C#, C++, VB, F#) as well as for fully configurable clients (with design-time browsing), where no programming on the part of the developer is necessary, and of course for any combination between these extremes. This is an important point, which will become clear when we contrast application development with ACOP.NET with other control system GUI builders such as Control System Studio (CSS) [3] and Java DOOCS Data Display (jDDD) [4]. Although Visual Studio is the GUI builder of choice, we will present other available options, for example on Linux. Examples using transport plugs for TINE [5], STARS [6] and EPICS Channel Access [7] will be given.

INTRODUCTION

The control system for a particle accelerator or other large facility must meet stringent requirements for stable operation. And it must offer diagnostic tools for spotting, finding and fixing problems as well as online and offline analysis tools for examining machine data and improving operations. This much goes without saying. Yet, the control system is often judged by its operational interface, i.e. at the presentation level.

There are several strategies for providing the operators, engineers, and machine physicists with useful control system applications. These applications can be provided by a controls group. Or application development tools can be given to the end users so that they might generate the controls applications themselves. Or … both. And note that the three groups of end users mentioned above will each have a different perspective as to what a controls application should be able to do. They are also likely to have different skill sets concerning programming abilities and understanding the various aspects of the machine being controlled.

A very common strategy is to have a controls group provide certain core applications, but to allow the operators and engineers to create control panels using some framework, where no programming skills are required, and where, more often than not, programming is not even possible. This is for instance the case of CSS, Taurus [8], and jDDD, each of which provides the panel developer with a rich set of displayer widgets, which can be attached to a control system address, and combined with other graphical widgets providing some display logic. Here it is assumed that there is no need to program any additional display logic, although this would be nominally possible with Taurus in a Qt environment.

Machine physicists, on the other hand, frequently need higher level control in order to ‘test things’ and improve the overall performance of the machine. That is, they need to be able to program at the client side. A common strategy here is to provide control system components in a mathematically based programming environment such as MatLab or Python (and NumPy).

This two-pronged approach, a panel builder for basic display and control applications, and MatLab or Python support for high level controls, is common to many accelerator facilities.

Yet another strategy is to support rich client development using rapid application development (RAD) tools. This approach has met with great success at HERA and PETRA-3 where RAD tools in either Visual Basic and ACOP ActiveX or Java and ACOP beans were used by both the controls group and machine physicists to develop applications [9].

We shall now describe ACOP.NET which provides a single application development paradigm, offering both a non-programming panel building environment as well as a fully-programmable environment (and of course any combination between these two extremes). In fact, a panel application without a single line of user code can be extended by supplying additional logic at any later date.

ACOP AND .NET

ACOP was originally designed as a RAD tool in the ActiveX world [1] and was predominately used in Visual Basic applications. It featured a very powerful chart, with a number of control system oriented features and a transport layer. It was later ported to java and expanded to include a variety of displayer beans suitable for rich client development in java [2].

Now, in general, rich client development in java requires more extensive programming skills than programming in Visual Basic. Thus, it is very tempting to offer a panel building framework with smart widgets which can be configured at design time and remove the programing aspect entirely from the application developer. This is in fact the approach of both CSS and jDDD, where an application might exist as an XML file

DEVELOPMENT OF ACOP .NET STARS TRANSPORT LAYER

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Abstract

Simple transmission and retrieval system (STARS) is an extremely simple and flexible software for small scale control systems with TCP/IP sockets. It is used by systems such as the beamline control system, and other systems at the KEK Photon Factory (KEK-PF). STARS works on various operating systems; therefore, STARS client developers can choose their preferred programming language. .NET is commonly used to develop graphical user interface (GUI) applications for beamline control at the KEK-PF.

Advanced component oriented programming (ACOP), which was developed by DESY, is very useful for GUI development, and a .NET version of ACOP was recently developed. ACOP communicates with various systems through a transport layer. We are currently developing ACOP .NET STARS transport layer. So far, we have succeeded in adding very primitive functionality.

OVERVIEW OF STARS

Simple transmission and retrieval system (STARS) is a software for small-scale control systems [1,2]. STARS consists of a STARS server and STARS clients. Each client is connected to the STARS server via a TCP/IP socket and handles text-based messages. The current version of the STARS server is written in Perl; therefore, STARS users can choose their preferred operating system and programming language for STARS client development.

Node Name and Hierarchical Structure

Every STARS client has its own unique node name that is used to identify the destination of the STARS text-based message. Figure 1 shows examples of STARS message transportation. If a STARS client that has “Term1” as a node name sends a text-based message of the form “Dev1 xxx”, the message will be delivered to the client “Dev1”. Hierarchical structure node names that are separated with a period “.” are available, and the server uses the first part of the node name as the destination.

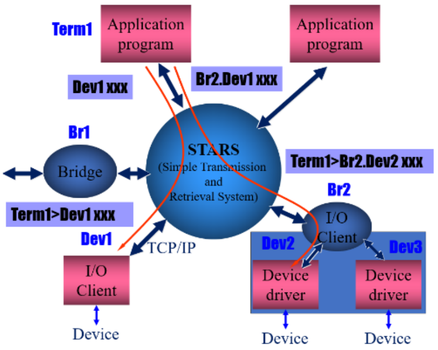

Figure 1: Message transportation on STARS.*

Command, Reply and Event

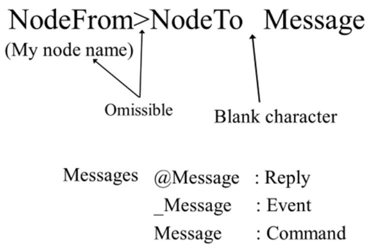

Figure 2: STARS message structure.*

Figure 2 shows the structure of a STARS message. The first part before “>” shows the origin of the message, and the next part before the first whitespace shows the destination of the message. The string which follows the first whitespace character can be either a command, a reply, or an event. A reply string starts with “@”, an event string starts with “_”, and a command string does not contain a preceding symbol. The strings can also contain values.

Event Delivery Function

STARS has an event delivery function. An event delivery request is registered by sending a “flgon” command to the server, which also has a node name “System”. Figure 3 shows an example the event delivery function. “Tm1” and “Tm2” request an event from “Dev1” by sending “System flgon Dev1” to the server. After the registration, if “Dev1” sends an event to the server, the message is delivered to “Tm1” and “Tm2”.

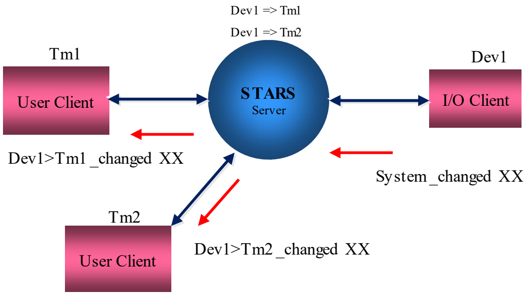

Figure 3: Event delivery function of STARS.*

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* Source: http://stars.kek.jp/

IMPROVING Web2cHMI GESTURE RECOGNITION USING MACHINE LEARNING

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Abstract

Web2cHMI is multi-modal human-machine interface which seamlessly incorporates actions based on various interface modalities in a single API, including finger, hand and head gestures as well as spoken commands. The set of native gestures provided by off-the-shelf 2D- or 3D-interface devices such as the Myo gesture control armband can be enriched or extended by additional custom gestures. This paper discusses a particular method and its implementation in recognizing different finger, hand and head movements using supervised machine learning algorithms including a non-linear regression for feature extraction of the movement and a k-nearest neighbour method for movement classification using memorized training data. The method is capable of distinguishing between fast and slow, short and long, up and down, or right and left linear as well as clockwise and counter clockwise circular movements, which can then be associated with specific user interactions.

INTRODUCTION

Zooming applications by performing a pinch gesture at touch-sensitive displays, talking with the personal assistant to retrieve information from the internet, or controlling video games through a gaming console recognizing arm and body motions are all popular and intuitive interface features currently in common use. These technologies, well known in the consumer market, have extremely enriched the way in which people interact with their devices. Even in the rather conservative market of industrial applications, novel interaction technologies are gaining in importance, e.g. to simplify quality assurance of manufacturing processes in the car industry or to improve the efficiency of warehouse logistics.

Today's users of accelerator control applications have developed intuitions based on click-like interactions. In an accelerator control room the mouse is still the standard user input device to interact with graphical applications. Being well accepted by the operators it provides a very accurate pointing capability and standardized user actions normally associated with graphical widgets. Mouse-based interactions are highly reliable unambiguous single-user actions. Therefore, any new interaction capability such as gesture or spoken command recognition will only be accepted by the users if they provide comparable or even better handiness, ease-of-use and reliability to click-like interactions.

This paper discusses a particular method and its implementation aiming at improving the quality and reliability in recognizing gestures based on different finger, hand and head movements using supervised machine learning algorithms. This includes a non-linear regression for extracting the features of the movement and a k-nearest neighbour method for movement classification using memorized training data.

Web2cTOOLKIT

The Web2cToolkit [1] is a collection of Web services, i.e. servlet applications and the corresponding Web browser applications, including

- Web2cViewer: Interactive synoptic live display to visualize and control accelerator or beam line equipment,
- Web2cViewerWizard: Full-featured graphical editor to generate and configure synoptic live displays,
- Web2cArchiveWizard: Web form to request data from a control system archive storage and to display the retrieved data as a chart or table,
- Web2cArchiveWizardWizard: Full-featured graphical editor to generate and configure archive viewer displays,
- Web2cToGo: Interactive display especially designed for mobile devices embedding instances of all kinds of Web2cToolkit Web client applications,
- Web2cGateway: Application programmer interface (HTTP-gateway) to all implemented control system interfaces,
- Web2cManager: Administrators interface to configure and manage the Web2cToolkit.

The Web2cToolkit provides interfaces to major accelerator and beam line control systems including TINE [2], DOOCS [3], EPICS [4], TANGO [5] and STARS [6].

Web2cHMI

The Web2cHMI [1] is a platform-neutral Web-based human-machine-interface implementation for accelerator operation and maintenance applications in the context of the Web2cToolkit Web service collection. It supports various modalities which can be used simultaneously including

- 1D/2D flat gestures including single-finger actions (mouse) and single- or multi-finger gestures (touch-sensitive display)
- 2D/3D spatial gestures including hand-gestures (LEAP Motion controller [7]), hand- or arm-gestures (Myo gesture control armband [8]) and 3-axis (yaw, pitch roll) head movements (smart glasses including Epson Moverio BT-200 [9] and Vuzix M100 [10])
- English spoken commands (Sphinx speech recognition [11]).

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LEVERAGING INTERNET OF THINGS DEVELOPMENTS FOR RAPID PROTOTYPING OF SYNOPTIC DISPLAYS

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Abstract

Recently the technology industry has been laying foundations for the eponymous Internet of Things (IoT): efficient publish-subscribe protocols; process control schemas for household items; and improved low-power radio communications. Accelerator controls and IoT have several aspects in common - small payloads, low latency, dashboard/synoptic data presentation format are some examples. The IoT now provides several open-source projects which can provide a partial implementation of one or more accelerator controls software features. Because development is typically a lower priority for accelerator controls groups, there is a valid case to try and utilise the free efforts of others for the benefit of accelerator controls. In this paper, the authors present examples of the use of IoT frameworks for synoptic display/GUI development. The work in this paper enables other developers to access this resource and experiment with their own systems.

INTRODUCTION

The IoT is a long-term upgrade of our global interconnectivity which aims to increase the efficiency with which we go about both our personal and professional lives. It will achieve this by adding remote interfaces to everyday items, deferring tedious interactions to increasingly intelligent computer algorithms. The deployment of this technology is slower than expected, especially as it requires standardisation and harmonisation which is less favourable when vendors are developing the technology.

However, we are starting to see the IoT enter our homes in the form of lamps and thermostats. In addition to commercial products, various suppliers along with the open-source community are now offering development platforms and software implementations to facilitate custom IoT solutions. Two of these solutions are of particular interest for controls applications at accelerators - “dashboards” and portable intelligent displays - which we have started to research for use with the EPICS deployment at Diamond Light Source (DLS).

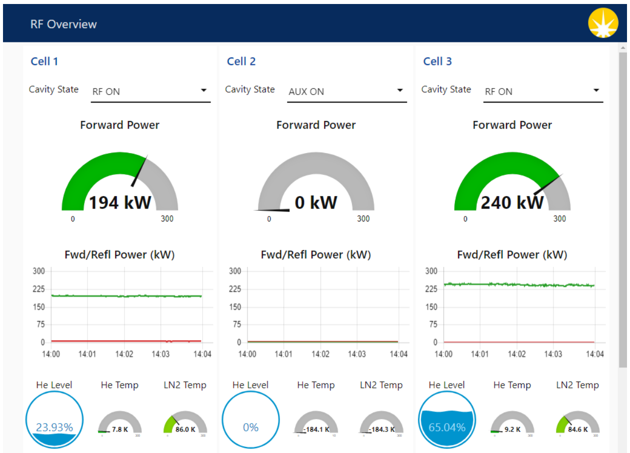
DASHBOARDS

The IoT uses software dashboards as a synoptic user interface (UI) to allow a broad overview of sensory data acquired from distributed devices. An example application could be location trackers attached to livestock, with the dashboard showing time spent at various locations and alarm notifications for individuals moving outside of the allowed area. This UI has a clear analogue with accelerator controls: the livestock are items of equipment, the UI shows performance and status data, and alarms check parameters against operating limits.

Where IoT dashboards can differ from classical controls synoptic UIs is extensibility and visual design. Dashboards need to be created by the user, so UI items are modular and easy to reconfigure. Most dashboard projects solely focus on the UI software itself, so more time is devoted to making the UI visually appealing and attractive. Although for many controls applications the latter point is not important, sleek synoptic displays are often desired around control rooms and high-level status screens. Another benefit of IoT dashboards is that they are often built to be fully responsive to different screen sizes and aspect ratios, including mobile devices. Existing UI solutions, such as Control System Studio [1], offer scaling of the display but are still not optimised for large interfaces on small screens. Where IoT dashboards are typically hosted as a web page, this means that a single interface can be designed and easily accessed on both workstations and mobile devices.

Node-RED Dashboard

Node-RED [2] is a locally hosted web-based visual programming tool for the IoT, written in Node.js [3] (a Javascript framework). It is similar in function to other websites which aggregate and translate packets from different IoT standards (e.g. IFTTT [4]), except that Node-RED uses flow-based graphical programming for configuration. Included in the base software is a UI dashboard, which communicates with the backend via WebSockets (see Fig. 1). The project is open source (Apache 2.0), and it is possible to implement new UI components. The responsive grid layout is well implemented and orders can be assigned to groups of components to help with arrangement on small displays.



Cavity State RF ON
Cavity State AUX ON
Cavity State RF ON

Figure 1: Example Node-RED UI dashboard showing a simple synoptic display.

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INTELLIGENT CONTROLS AND MODELING FOR PARTICLE ACCELERATORS AND OTHER RESEARCH AND INDUSTRIAL INFRASTRUCTURES

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Abstract

We give some perspective on the present state of intelligent control for particle accelerators. This is based on our experience over the past 14 years in developing artificial-intelligence-based tools specifically to address modeling and control challenges found in particle accelerator systems.

INTRODUCTION

Despite the rush to incorporate artificial intelligence (AI) into every component of our lives, not all systems (or subsystems) require intelligent control or data analysis for reliable operation. As the old saying goes, “Just because you can [build it/use it] doesn’t mean you should.” Some systems, however, can greatly benefit from the responsible and well-architected incorporation of control techniques with intelligent characteristics.

Although other fields, such as computer vision and web search engines, were quick to adopt AI or AI-like tools, the field of accelerator physics has been more reluctant. However, things have advanced in several areas, such as computing and data collection, and these advances have truly enabled the research and subsequent application of AI techniques to particle accelerator. But, as with anything new, the APS News (June 2018, “AI Makes Inroads in Physics”) notes there are still challenges [1].

Here we review several examples of complex systems that can benefit from intelligent control methodologies, i.e., cases that were otherwise under-responsive when simpler, less advanced approaches were applied. The case examples on which we focus deal with particle accelerators that are used in many disciplines including fundamental discovery science and engineering.

ACCELERATOR CHALLENGES INTERESTING FOR INTELLIGENT CONTROL AND MODELING SCHEMES

Upon examining the machines used for physics we note that since 1938, accelerator science has an estimated influence on almost one-third of physicists and physics studies, and on average contributed to physics Nobel Prize-winning research every 2.9 years [2]. Further, as one example of the prevalence of particle accelerators, we look to the United States. In support of its science mission, the U.S. Department of Energy (DOE) operates large scientific instruments that support the work of more than 50,000 scientists worldwide. Large particle accelerators are at the core of eleven of the seventeen National User Facilities that DOE operates. Particle accelerators also have roles in the industrial, medical, security, defense, environmental, and energy sectors. The performance goals and complexities of particle accelerators are ever increasing to meet the needs of the science and applications.

Several characteristics of the more complex existing and future particle accelerators are interesting for employing intelligent controls or modeling schemes. For instance, there are many parameters to monitor and control in various sub-systems, and accelerators have many interacting sub-systems. Applications can have on-demand, fast changes in the accelerator operational states. Accelerators can have many small, compounding errors. The accelerator physics of certain machines can be riddled with complex and/or non-linear dynamics having potential detrimental instabilities or other collective effects for effective machine operation. Often, the machine model does not resemble the as-built machine, so there are challenges in diagnosing and/or interpreting the operational behavior from day one of operation. Accelerator systems often exhibit time-varying and non-stationary behavior. Diagnostics for the beam, systems, and peripherals are also often limited because of cost, space, and the inability to physically characterize the overall system at all locations. In addition, even when diagnostics are in existence, they are often not put to full use in control schemes (e.g., images). A final concern is that systems or system peripherals are re-purposed in “new” machines, meaning that the equipment was not originally intended for use in such a configuration/specification.

WHAT DO ARTIFICIAL INTELLIGENCE (AI) AND RELATED TERMS MEAN?

The exact definitions of artificial intelligence and its related techniques are somewhat fluid in terms of interpretation in the community. Figure 1 attempts to help the reader classify the areas of artificial intelligence and related areas covered in this paper [3].

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CURRENT STATUS OF THE RAON MACHINE PROTECTION SYSTEM DEVELOPMENT

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Abstract

For the RAON accelerator that transports beams with high energy and power, a machine protection system (MPS) that protects each device from sudden beam loss is necessary. For this reason, we have been preparing for the development of the MPS with the start of the RAON accelerator construction. For effective MPS operation and stable accelerator operation, we divided the MPS into four subsystems: fast protection system, slow interlock system, run permit system, and post-mortem system. Among them, the FPGA-based fast protection system and the PLC-based slow interlock system have been tested by prototypes and are currently working on the mass production. The run permit system and the post-mortem system are also undergoing basic design and software development. In this paper, we will describe the progress of the MPS development through detailed hardware and software development in the RAON accelerator and explain the future plans.

INTRODUCTION

The RAON accelerator [1] produces various kinds of beams from proton to uranium to accelerate and transport to the target in the experimental hall. These beams can be accelerated to an energy of about 200 MeV/u, with a power of up to 400 kW. Various devices such as ion sources, magnets, superconducting cavities, etc. are installed to generate and accelerate beams, and sudden interlocks in the devices lead to the beam loss during operation. This beam loss can cause significant damage to the device, and therefore a machine protection system (MPS) is required to minimize such damage in the RAON accelerator. Currently, we are developing the MPS into four parts for efficient operation: a fast protection system (FPS), a slow interlock system (SIS), a post-mortem system (PMS), and a run permit system (RPS). First, the FPS is fabricated on an field programmable gate array (FPGA) basis and collects interlock signals from the beam loss monitor (BLM), beam current monitor (BCM), low-level radio-frequency (LLRF) system, etc. within a few tens of microseconds and sends the beam stop signal to the mitigation devices like a chopper, RFQ LLRF, and so on. Secondly, the SIS is fabricated on programmable logic controller (PLC) basis and collects interlock signals from devices such as cryogenics, vacuum, etc., and transmits interlock information to the FPS within a few tens of milliseconds. Thirdly, the PMS is a system for storing and analyzing information of interlock signals to prevent future accidents. At last, the RPS is a system for determining beam operation status by checking the state of accelerator devices corresponding to a machine mode and a beam mode before operation. Figure 1 shows the configuration of the RAON MPS.

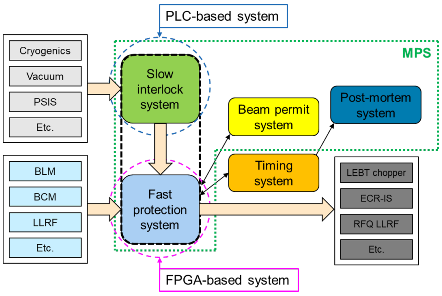

Figure 1: Layout of the RAON machine protection system. The machine protection system consists of the fast protection system, the slow interlock system, the post-mortem system, and the run permit system.

FAST PROTECTION SYSTEM

The RAON FPS consists of a mitigation node acting as a master and an acquisition node acting as a slave. This FPS consists of two mitigation nodes including a back-up and dozens of acquisition nodes as shown in Fig. 2. The prototype of the FPS was developed in 2016 and successfully tested at the RISP test facility. The test results of the prototype were presented at ICABU2017 workshop [2]. Based on these results, The FPS product, including one mitigation node and seven acquisition nodes, is currently under development [3] and will be finished at the end of 2018.

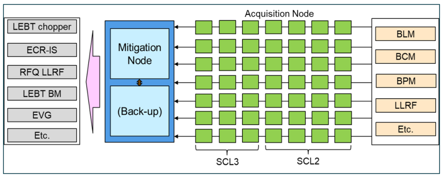

Figure 2: Layout of the fast protection system which has mitigation nodes and acquisition nodes. The acquisition node collects the interlock signals, and the mitigation node sends signals to mitigation devices.

The Mitigation node is manufactured using Xilinx Zynq ultrascale+ XCZU9EG chip. In this node, eight SFP+ transceivers are installed for optical communication, and 24 sub-miniature version A (SMA) ports are located on the back panel for signal transmission with mitigation devices. The printed circuit board (PCB) of the mitigation node is now being manufactured, and the test is in progress. Figure 3 shows the wiring diagram of the mitigation node. The

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MARVIN UPDATE – THE ROBOTIC SAMPLE MOUNTING SYSTEM AT THE EMBL-HAMBURG

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Abstract

This article aims at giving an overview about the controls of the robotic sample mounting system MARVIN (MultiAxesRoboticVersatileINstaller) that are installed at EMBL beamlines at the PETRA III synchrotron (DESY, Hamburg, Germany). Currently, two inhouse built systems are in user operation at the beamlines P13 and P14 dedicated to macromolecular crystallography (MX). The different sub-systems and the embedding into BICFROK, the EMBL Hamburg beamline's control framework [1], and especially, new developments to decrease downtimes, as well as system recovery routines, will be described in detail.

INTRODUCTION

Robotic sample mounters are state-of-the-art instrumentation at protein crystallographic beamlines [2]. In general, their function is to mount and dismount sample holders with cryogenically frozen protein crystals onto the head of a diffractometer axis. Samples are stored in liquid nitrogen (LN2) filled dewars and rapidly transferred by the robotic system into a cold gaseous nitrogen stream in order to increase their lifetime in the synchrotron beam. The standardized SPINE sample holders [3], that are used with this instrument and that consist of a cap and a pin with the microscopic crystal attached to its tip, are individually inserted into containers called pucks [4]. In the pucks used for MARVIN and developed by EMBL [5] ten sample holders can be inserted see Fig. 1.

As the robotic systems can considerably improve speed and reliability of the mounting, the EMBL in-house development of a first similar system started already in 2002 and was initially in user operation at a former DORIS synchrotron beamline BW7b at DESY [6]. In 2013, the commissioning of the first new MARVIN system equipped with a Stäubli industry robot TX60L [7] began. The first system is in user operation since 2014 and the second system serving a diffractometer with vertical spindle axis operates since 2016 at the P14 beamline. In 2017, about 30000 samples have been mounted with the two systems.

SUB-SYSTEMS AND INTERFACING

The robot is installed overhead inside a closed cage centred above the LN2 storage dewar. In this dewar 170 SPINE samples in 17 pucks can be stored. The sample storage dewar is equipped with a pneumatically driven lid to open and close the dewar. The LN2 level inside the dewar is maintained by an automatic filling system fed from a central LN2 supply.

Apart from mounting the samples the system has also other functions. After a user has inserted a puck manually on a dedicated loading base, the robotic system distributes it automatically to one of the storage bases. The sample mounting takes always place from the central base. Therefore, a puck has to be shuffled automatically onto the central base before sample mounting.

In order to guarantee a high degree of automation and a high sample throughput as well as a high level of safety, the interaction with several other components is required. Apart from the sub-systems belonging to the core of the MARVIN system like the industry robot, the storage dewar with position sensitive puck switches, the cryogenic system for the dewar refilling, the pneumatic system for the control of lid, robot gripper and a guillotine shutter installed at the robot cage and the safety system, independently controllable instruments have to be interfaced and procedures synchronised. These devices are the diffractometers like the 'MD3' [8], experimental tables, the area detectors mounted on detector translations, cryogenic gasflow sample cooling units, and fluorescence detectors for anomalous phasing experiments.

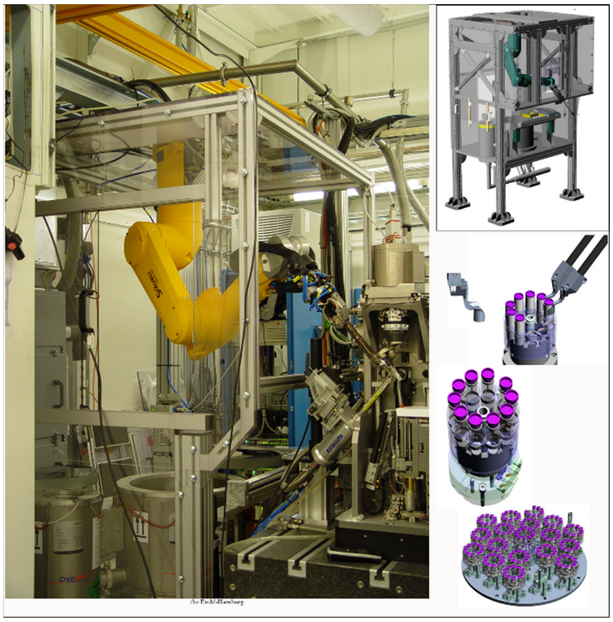

Figure 1: MARVIN mounting a sample on the MD3 Goniometer. And robot gripper, samples Pucks and Puck storage plate on the right.

Redundant signals and sensor cross-checks have been added in order to improve the reliability of the system. Examples are a vial detection switch at the robot grippers, gripper temperature control to avoid icing of the robot grippers, detection of the opening state of the grippers, tool changer detection signal and a crash protection state signal. While in the first sample changer system no detection of samples and pucks was present redundant sensors check in the current system the positioning accuracy to avoid sample losses and deformations of the grippers and potential damaging of the other instruments involved in the process.

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REAL-TIME AND DETAILED PROVISION OF J-PARC ACCELERATOR OPERATION INFORMATION FROM THE ACCELERATOR CONTROL LAN TO THE OFFICE LAN

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Abstract

J-PARC Main Ring (MR) is a high-intensity proton synchrotron whose control system is developed based on EPICS. Its beam operation started in 2008, and since 2009 has been delivering beam to the T2K neutrino experiment and hadron experiments. Over the past decade, MR have become more sophisticated and more stable driving is required. Along with this, demands arose from users and experts of equipment such that acquiring detailed and real-time information on the apparatus from the office LAN. On the other hand, the accelerator control system is quarantined from the office LAN with firewall for security reasons. Therefore, despite being intentional or not, manipulating any equipment in the accelerator control LAN shall be prohibited from the office LAN. This article describes construction and prospects of such an one-way gateway system such that information is relayed via EPICS from accelerator control LAN to the office LAN while minimizing influence in the opposite direction.

INTRODUCTION

The office LAN in J-PARC is named “JLAN”.

J-PARC accelerator operation information has been provided to JLAN in a web page containing two items as following:

- “Latest Operation Status” which is manually typed by the accelerator shift leader as necessary.
- A image file showing summary of operation status, which is updated every one minutes.

Its example is shown in Fig. 1.

As MR become more sophisticated since it stated its operation in 2008, yet more stable operation is required. Accordingly, demands from equipment experts and users are increasing to acquire real-time and detailed status of the accelerators and equipment from their office. Those information such as

- detailed status of power supplies for magnets and RF,
- Present value of beam pipe vacuum as well as its history,
- Temperatures in power supply buildings and their history,

were only available in the control LAN but in JLAN.

EPICS AND CA GATEWAY

The control system of J-PARC Accelerator is based on EPICS [1]. Its protocol is called Channel Access (CA). CA is available within the same network under normal usage.

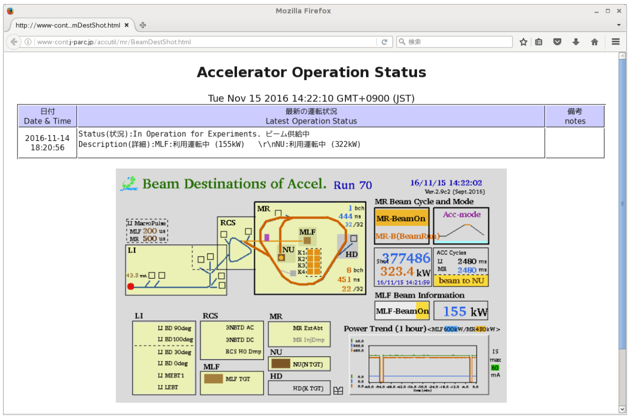
A front-end computer, which provides control points to access equipment under its control, is called I/O controllers (IOC). The operator interface (OPI), which act as a CA client, broadcasts UDP packet to search for a control point of interest. IOC will reply to the client when it is hosting the requested control point.

CA Gateway [2] is a standard EPICS utility to relay CA between two networks. It works as a CA client in one network and a as server in the other, so that accelerator operation status information in the control LAN will be available in JLAN in realtime.

MINIMIZATION OF INFLUENCE TO THE ACCELERATOR CONTROL LAN USING TWO-TIER GATEWAY

Accelerator control LAN is connected to JLAN via a firewall device. There is DMZ in the middle of those two networks, which is called “control-DMZ”. The policies in communications among those three networks are as following:

- No bridge connection is allowed other than the firewall device. Therefore any communication shall go through the firewall.
- Any direct communication between control LAN and JLAN is prohibited.
- Communication between control LAN and control-DMZ is allowed only if source IP address, destination IP address, and port number is listed in a whitelist.
- Communication between control-DMZ and JLAN is also limited by another whitelist.



Accelerator Operation Status

Tue Nov 15 2016 14:22:10 GMT+0900 (JST)

日付 Date & Time	最新の運転状況 Latest Operation Status	備考 notes
2016-11-14 18:20:56	Status(状況):In Operation for Experiments. ビーム供給中 Description(詳細):MLF:利用運転中 (155kW) \r\nNU:利用運転中 (322kW)	

Figure 1: A web page which shows J-PARC accelerator status.

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DEVELOPMENT AND CURRENT STATUS OF KURAMA-II[*]

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Abstract

KURAMA-II, a successor of a carborne gamma-ray survey system named KURAMA (Kyoto University RAdiation MApping system), has been developed and applied to various activities related to the nuclear accident at TEPCO Fukushima Daiichi Nuclear Power Plant in 2011. KURAMA-II has established its position as an effective method for the radiation monitoring method in environment. The development of KURAMA-II is still on the way to extend its application areas such as the trial to port the system to a single-board computer or the development of a new cloud service. In this paper, the current status of KURAMA-II on its developments and applications along with some results from its applications are introduced.

INTRODUCTION

The magnitude-9 earthquake in eastern Japan and the following massive tsunami caused a serious nuclear disaster for the Fukushima Daiichi nuclear power plant. Serious contamination by radioactive isotopes was caused in Fukushima and surrounding prefectures, but the existing radiation-monitoring schemes were incompetent for this situation due to damage and chaos caused by the earthquake.

KURAMA [1] was developed to overcome difficulties in radiation surveys and to establish air dose-rate maps during and after the incident. The design of KURAMA was intended to enable a large number of in-vehicle apparatuses to be prepared within a short period of time by using consumer products. The in-vehicle part of KURAMA consists of a conventional radiation survey meter, a laptop PC, a USB-type GPS dongle, and a 3G pocket wi-fi router. The data-sharing scheme based on Dropbox, a cloud technology, has enabled high flexibility and scalability in the configuration of data-processing hubs or monitoring cars. KURAMA succeeded in the simultaneous radiation monitoring extended over a wide area such as Fukushima prefecture and the eastern Japan, in contrast to other conventional carborne survey systems lacking of scalability.

As the situation became stabilized, the main interest in measurements moved to the long-term (several tens of years) monitoring of radiation from radioactive materials remaining in the environment. KURAMA-II [2] was developed for such purpose by introducing the concept of continuous monitoring from vehicles moving around residential areas, such as local buses and postal motorcycles. The ruggedness, stability, autonomous operation and compactness were well taken into consideration in its design, and an additional measurement capability of pulse-height information along with location data was also introduced. KURAMA-II has been successfully introduced to the continuous monitoring in residential areas and other monitoring activities.

In this paper, the outline and the current status of KURAMA-II along with some results from its applications are introduced.

KURAMA-II

System Outline

The system outline of KURAMA-II is shown in Fig. 1. The in-vehicle part is based on CompactRIO to obtain sufficient ruggedness, stability, compactness and autonomous operation feature. The radiation-detection part of KURAMA-II is the C12137 series by Hamamatsu Photonics [3], a CsI(Tl) detector series characterized by its compactness, high efficiency, direct ADC output and USB bus power operation. The size of CsI(Tl) scintillator varies depending on the usage, typically 3.4 cc for conventional carborne surveys. The ambient air dose rate, $H^*(10)$, is calculated from the pulse height spectrum obtained for each measurement point by using G(E) function method [4–6]. Since the energy dependence of detector efficiency is properly compensated by the G(E) function, more reliable results are expected in the case of environmental radiation that is dominated by γ-rays scattered by air, soil, or buildings etc. All components of the in-vehicle part are placed in a small tool box (34.5 cm × 17.5 cm × 19.5 cm) made of wood covered with thin aluminum sheet for the better handling.

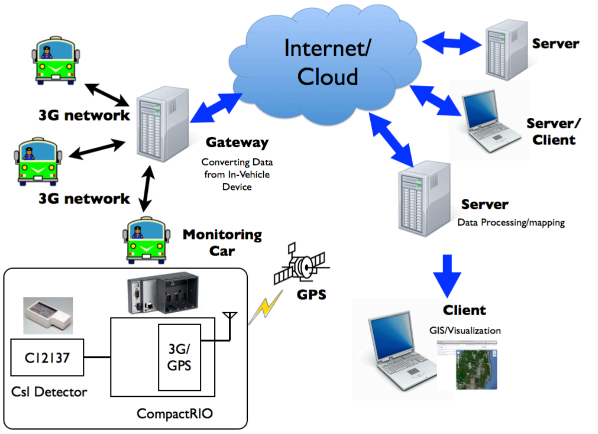

Figure 1: The system outline of KURAMA-II.

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RELIABILITY IMPROVEMENT FOR THE INSERTION DEVICE CONTROL IN THE TPS

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Abstract

Insertion devices (ID) are essential components in third-generation synchrotron light sources, which can produce highly-brilliant, collimated and quasi-monochromatic radiation over a broad energy range for experiments. Reliable operation of the insertion devices is important to users of beamlines. The most unpredictable fault is due to a soft error in optical absolute encoders due to radiation. There are several solutions to avoid such faults, e.g. by increasing the distance of the encoder from the beam, by a lead shield cover and finally by adopting an auxiliary position sensing device to help recovery from a fault. Efforts to improve operational reliability of the TPS ID controls will be discussed.

INTRODUCTION

The TPS includes one EPU46, two EPU48s and seven IUs (In-Vacuum Undulator) which are installed in seven straight sections to meet experimental requirements in phase I beamlines of the TPS project [1-4]. The ID control system was developed including gap/phase motion, protection system (hardware and software) and GUI development. All control systems for insertion devices are done by the NSRRC control team for economic reasons and delivery of a similar ID control environment is the goal.

The EPU48 includes six axes servo motors. Two servo motors control the gap, one on the upper girder and one on the lower girder. The other four servo motors control the phase, two on the upper and two on the lower girder. Each axis servo motor is connected to a rotary absolute encoder. In addition, each servo axis is tracked with a TR absolute linear encoder with 0.1 µm resolution, providing direct gap sensing and frame reference to eliminate effects of backlash. The EPICS IOC performs a software tilt calculation based on the linear encoder feedback in addition to the tilt sensors. With gap / phase change, the corrector magnets for IDs require very sensitive power supply controls to maintain very stringent beam stability requirements.

Our control plan for the phase-I insertion devices is based on the standard TPS cPCI EPICS IOC. The motion controller is based upon the Galil DMC-40x0 series Ethernet based motion controllers [5]. The controller is a full-featured motion controller packaged with multi-axis drives in a compact, metal enclosure. It controls the motors based on commands via Ethernet and receives commands from the EPICS IOC to handle motor motion and to read encoder positions, limit switches, position error and other states for monitor and software protection.

The motion controller is suitable for servo motors (EPU46, EPU48) and stepper motors (IU22). Closed loop gap adjustment is needed for varying phases of the EPU48 and EPU46. It can be copied with changing forces between upper and lower magnetic arrays. All motion axes include a synchronous serial interface (SSI), where the optical encoder connects to the motion controller directly. Each motion axis is accompanied with limit switches for over-travel protection. Synchronization of gap motion axes is essential to prevent tilt of the beam.

The hardware configuration for the TPS ID control is shown in Fig. 1 including cPCI EPICS IOC, 128 bits DI/DO module, ADC/DAC IP (Industry Pack) modules, motion controller, temperature monitoring solution and RS232/422/485 based devices of the insertion frame. High precision power supplies are used to control corrector magnets from feed forward look-up tables. Current designs include also the control interface for the beamline, e.g. the IU22 controls include an ion pump and ion gauge interface.

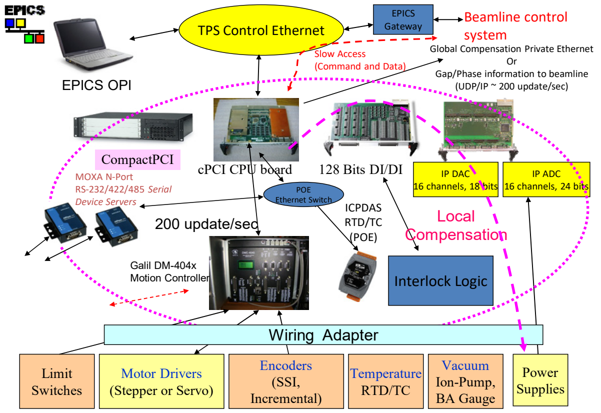

Figure 1: Basic hardware configuration for TPS insertion devices in Phase-I.

RADIATION EFFECT ON OPTICAL ABSOLUTE ENCODERS

Particle accelerators produce high energy protons and electrons, and the secondary particles produced by their interactions produce significant radiation damage on most semiconductor electronics components.

A single event effect (SEE) may be an electrical disturbance that disrupts the normal operation of a circuit. It is caused by the passage of a single ion through or near a sensitive node in a circuit. Single event effects can be either destructive or non- destructive.

Single-event upsets (SEU) or transient radiation effects in electronics are state changes of memory or register bits caused by a single ion interacting with the chip. They do not cause lasting damage to the device, but may cause lasting problems to a system which cannot recover from

LONG-TERM STABILITY OBSERVED BY ELECTRON BPM AND PHOTON BPM FOR TAIWAN PHOTON SOURCE

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Abstract

TPS is 3-GeV synchrotron light source which has opened for public users since September 2016 and now offers 400 mA top-up mode operation. The requirements of the long term orbit stability and orbit reproducibility after beam trip have been gradually more and more stringent and become a challenge from users' request. Furthermore, the thermal effect would be expected to be worsen after 500 mA top-up operation which should deteriorate the orbit drift. The report investigates the long-term orbit stability observed from electron BPM and X-ray BPM and also evaluates the possibility of the local XBPM feedback to improve photon beam stability.

INTRODUCTION

The TPS requires beam position stability of less than 10% of the beam size to provide advanced experimental capabilities at the 3rd generation light source. Therefore, FOFB and RF frequency compensation have been adopted to stabilize the electron orbit [1][2]. Besides, to monitor the position and stability of photon beams, two-blade type X-ray beam position monitors (XBPMs) are installed in beamline frontends and beamlines[3][4]. It is observed that the thermal effect would cause the mid-term orbit disturbance at the first 30 minutes after the beginning of beam stored and long-term slowly drift for the following 4~5 hours before it achieves the equilibrium, especially in the vertical plane. Besides, there are also obvious daily position change along with temperature variations and periodic 4-minutes variation consistent with injection cycle. Furthermore, insertion device (ID) gap/phase change is also significantly affect position stability where it is partly caused by deformation and resulted in BPM mechanics displacement and partly still due to thermal effect. The position drift/fluctuation seemed to be able to be controlled below several microns or even sub-micron in electron BPM. However, the errors would be amplified several times observed at the end of beamline XBPM. This report summarized the long-term orbit drift observed by electron BPM and photon XBPM. The preliminary local XBPM feedback test is also proposed to minimize the errors.

PHOTON BEAM POSITION MONITOR LAYOUT AND ELECTRONICS

There are seven beamline open to users in TPS now. For each beamline, there are different types of X-ray or photon beam position monitors are used to detect the synchrotron radiation. The blade-type X-ray BPMs (XBPM) [3] is standard equipment installed at each front-end; quadrant PIN photodiode BPMs (QBPMs) [4] are adopted by few experimental end station. The layout of front-end instrumentation is shown as Fig. 1. XBPM1 is completed calibration and observed reliable for a while. However, the calibration of XBPM2 is not yet completed and it was observed that the horizontal and vertical readings of XBPM2 had serious coupling. Therefore, only XBPM1 is presented and included for feedback in this report. About acquisition electronics, three types of electronics had been used and evaluated. The first one uses the FMB Oxford F-460 to convert current to voltage and read the voltage with a NI-9220. The second type of electronics is a home-made device with a 0.5 Hz update rate. The third type is the commercial product and now our majority: Libera Photon which could provide different data flow for different purpose of analysis, including 10/25 Hz streaming, 5 kHz/578kHz waveform with trigger as well as post-mortem functionalities.

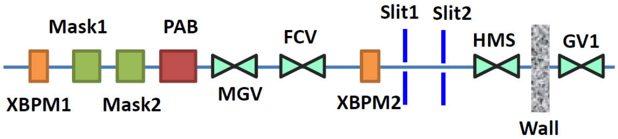

Figure1: Layout out of front-end instrumentation.

OBSERVATION OF ORBIT STABILITY BY BPM AND XBPM

Position Drifts After Beam Restored

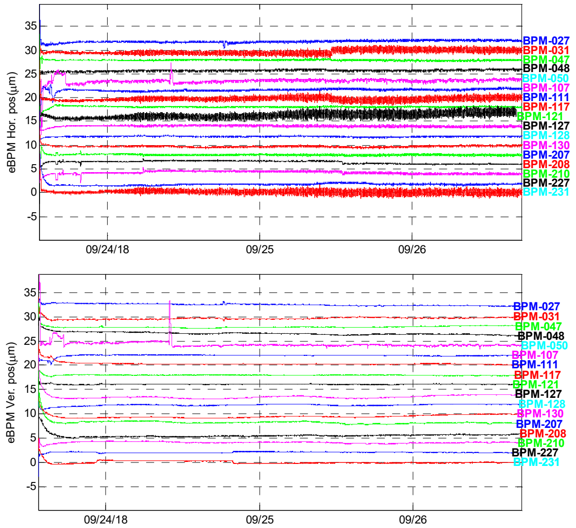

Figure 2: The upstream and downstream electron BPM reading nearby IDs for three days after beam restored.

It could be observed the upstream and downstream electron BPM nearby 7 IDs as Fig. 2 at first beginnings of beam stored, the position drift of some BPMs would be

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DESIGN AND IMPLEMENTATION OF STEPPER MOTOR CONTROL OF THE LINAC HIGH POWER RF SYSTEM BASED ON FPGA

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Abstract

In this paper, the new motion control system that governs the position of high power attenuators and phase shifters in the linac's RF system at SLRI is described. The drive system, which was originally driven by a set of AC reversible motors, is replaced by a new set of stepper motors. The hardware selection and installation is presented in detail. The digital control circuits are designed in VHDL and implemented on a commercial Field Programmable Gate Array (FPGA) board. The main software part, implemented in MicroBlaze Microcontroller System (MCS), is coded in C to control the position of stepper motors relative to the DC voltage reference points of the hardware system. A LabVIEW GUI is designed to interface with the control system to provide reference points and display position values via RS-232 and PLC interfaces. This stepper motor control system can be used to effectively implement the phase and amplitude control system of the linac's RF signals in the future.

INTRODUCTION

Synchrotron Light Research Institute (SLRI) has been operating its synchrotron facility complex called SIAM Photon Source (SPS) to serve various research activities since December 2001. Its 40-MeV linac has been regularly operated only twice a day, with an approximate duration of one hour each, for electron injection. The linac consists of five different parts to accelerate the electron beam. These parts are pre-buncher 1, pre-buncher 2, buncher, a 20-MeV accelerating tube 1, and a 20-MeV accelerating tube 2 [1]. The phase and amplitude of a 2,856 MHz pulsed-RF are controlled manually by adjusting the high power phase shifters and attenuators, respectively. The mechanical parts of these high power elements consist of seven piston rods along the RF distribution waveguides depicted in a diagram in Figure 1. They are operated as controlling actuators for adjusting the phase shifters and amplitude attenuators. They had been driven by reversible AC induction motors since the beginning of the first light.

Even though the phase and amplitude of the RF signal along the waveguides can be adjusted, the actual numerical values of these RF parameters are not directly measured. During the normal operation, the position of each of the piston rods; i.e., the position of each of the phase shifters and amplitude attenuators, is referenced to the DC voltage across potentiometer in a motor drive circuit. This voltage is displayed at the electronic front panel in a control room as shown in Figure 2. Each day this set of values is recorded as RF operating point for beam injection and future reference. The operating point is occasionally changed if beam injection problem occurs or machine parameters are needed to be changed.

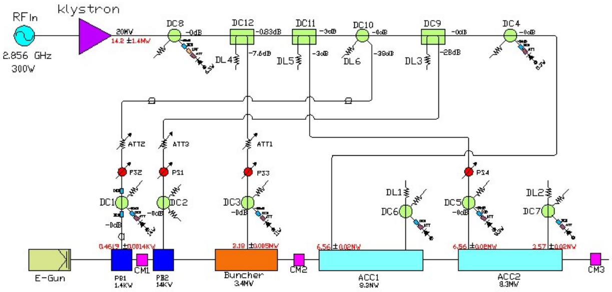

Figure 1: Linac RF distribution diagram.

Figure 2: Electronic front panel display of the phase shifters and amplitude attenuators as DC voltages.

In this paper, new hardware selection and installation is described in the next section. Digital control circuit design of the system on FPGA board is also included. Software implementation and GUI are presented in the following section. System performance and conclusion are presented at the end of this paper.

HARDWARE

Stepper Motors, Electronic Drivers and Controllers

During annual shutdown in 2013 all reversible AC induction motors driving the high power phase shifters and amplitude attenuators were replaced by commercial stepper motors and their electronic controllers. The selected stepper motors and controllers are Oriental Motor's RK Series with Pulse Input Type and RKII Series with Built-in Controller Type, depending on the size and location of the phase shifters and amplitude attenuators in the linac system. The new motors were carefully chosen to meet mechanical characteristics and intended to provide better position control of the phase shifters and amplitude attenuators. Figure 3 shows an example of the motor replacement in the waveguide system. All electronic motor drivers and

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COLLIMATOR MOTION CONTROL SYSTEM UPGRADE FOR MEDICAL LINEAR ACCELERATOR PROJECT AT SLRI

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Synchrotron Light Research Institute, Nakhon Ratchasima, Thailand

Abstract

A prototype of the 6-MeV medical linear accelerator has been under development at Synchrotron Light Research Institute (SLRI). A set of secondary collimators is utilized with different size arrangement for beam shaping purpose. To produce the desired field size of the beam, the FPGA-based collimator motion control is designed in VHDL for simultaneous control of the collimators while the main PI control is implemented in the FPGA's main processor. In this paper, hardware and software upgrades of the collimator motion control system are presented. A custom drive hardware for individual collimator is designed to implement with the existing FPGA controller board. Interface between the custom hardware parts and the FPGA's programmable logic (PL) part is described. Communication between the motion control subsystem and the main LabVIEW control software on PC is modified to send and receive parameters wirelessly. Software modification of the FPGA's main processor part and that of the LabVIEW GUI part is also reported.

INTRODUCTION

Currently, SLRI has been developing a prototype of the 6-MeV medical linear accelerator for cancer treatment. Reverse engineering approach has been employed in this research and development via a donated machine. The prototype consists of several subsystems, for examples, a linear accelerating structure, a 3.1-MW magnetron, a solid-state modulator, drive stand, a linac treatment head, and a central control system. All subsystems are connected to the central control system in a private network as shown in Figure 1. Introductory detail of this machine prototype can be seen in [1].

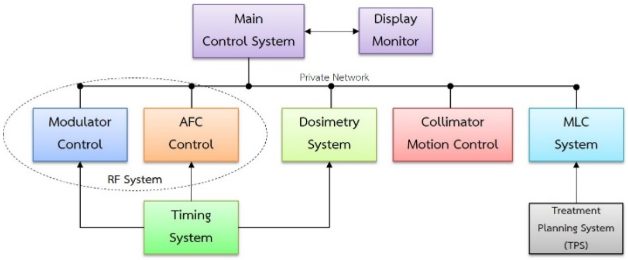

Figure 1: Network diagram of the machine prototype.

The FPGA-based motion control of collimators, both hardware platform and software implementation, is explained in detail in [1]. The main hardware parts consist of the secondary collimators and their drive PCBs, the Digilent's Zedboard and the 8-channel bipolar simultaneous sampling ADC (Analog Devices' EVAL-AD7606SDZ), and the digital IP blocks designed by VHDL in the programmable logic (PL) part of the FPGA. Digital feedback control utilizing PID controller for each of the collimator and the interface between hardware and control software, including LabVIEW GUI, are also described. The performance of the developed system is very satisfactory in order to control all collimators simultaneously.

In this paper, hardware modification and upgrade are presented. In-house electronic parts and custom drive system for individual collimator and the implementation with the existing FPGA controller board is described. Wireless communication and software development, together with the data transfer to the LabVIEW GUI for monitoring purpose, are explained. System performance and conclusion are discussed at the end of the paper.

HARDWARE

Several hardware parts of the motion control system have been designed and upgraded. Major modifications for this new system are new custom electronic PWM drive PCBs, DC power supply modules, wireless development boards, and a new ADC module. Each of them is explained in this section.

Custom PWM Drive PCBs

Since there are two adjustable pairs of collimator jaws in the linac treatment head with one pair installed above the other to provide symmetric and asymmetric fields, the motors that move the collimators must be driven independently. Traditional H-Bridge circuit based on IR8200B is used to provide appropriate voltage to control the motor speed with PWM signal. A custom PWM drive PCB is designed to drive a motor and to receive four signals from external controller board to control IR8200B. These four signals are PWM, Direction, Brake, and Motor Enable, and they are provided by the PL part of the Zedboard controller through the rear connector of the equipment box. This custom PCB is installed in a standard equipment box as shown in Figure 2. Each box also contains a wireless development board which will be described in the subsequent subsection.

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UPGRADING THE SYNCHRONISATION AND TRIGGER SYSTEMS ON THE VULCAN HIGH-POWER Nd:GLASS LASER

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Abstract

The Vulcan Neodymium-Glass High-Power Laser Facility at the Central Laser Facility [1] in the UK has been operational for over 40 years providing a world-leading and high-profile service to the international researchers in the field of Plasma Physics. Over that time the facility has had many modifications and enhancements to the buildings, the laser hardware and to the computerised control, synchronisation and timing systems.

As the laser systems have developed and the user experiments have continued to become much more complex and demanding, many new operational conditions have been required. The use of four independent laser oscillators with different properties - including temporal, spectral and operating frequencies - have meant that the optical and electrical multiplexing and the timing and synchronisation systems have all had to be adapted and extended to cope with these additional needs. However, these changes have resulted in the build-up of the overall system jitter to ± 250 ps between long (nanosecond) and short (picosecond) optical pulses and this is a limiting factor for time-critical experiments.

This paper will present some of the key changes and improvements that have recently been made.

INTRODUCTION

To significantly enhance the performance of the laser a number of key elements have had to be addressed - the number of different short-pulse oscillators have been reduced to two, namely a Spectra Physics [2] Tsunami Titanium: Sapphire oscillator and a Spectra Physics InSight DS oscillator and also the synchronisation and electronic timing systems have been replaced.

With the use of a commercial "Lok to Clock®" system on the Tsunami oscillator, the number of RF frequencies have effectively been reduced to one as this oscillator is now forced to operate at and in phase with the 79.926 MHz ± 80 Hz RF provided by the InSight oscillator.

This has enabled the fundamental timing system to be replaced with a commercial Master / Slave system from Greenfield Technology Ltd [3]. Figure 1 shows a schematic of the laser facility complex and the distribution of the new timing system. The system comprises of a model GFT 3001 Master Oscillator and

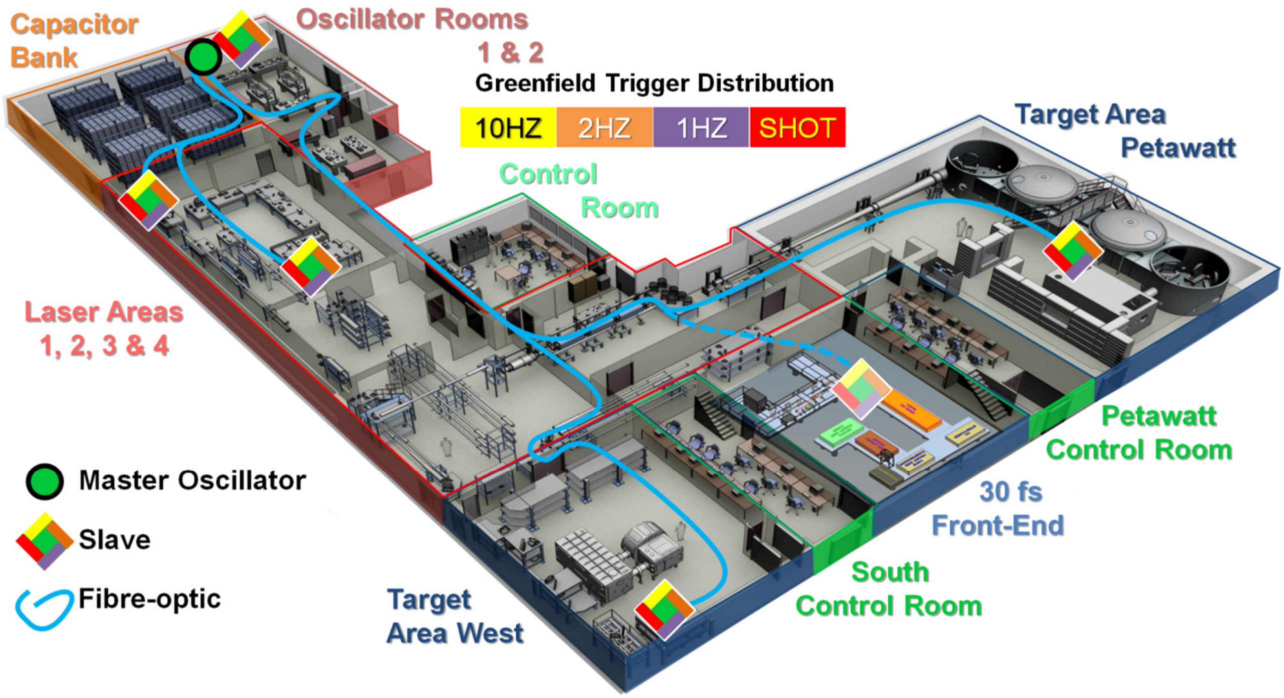

Figure 1: Schematic of the Vulcan Laser Facility showing the installation of the new trigger system. The Greenfield GFT 3001 Master Oscillator is located in Oscillator Room 2 with the GFT 1004 Digital Delay Generator modules widely distributed around the Facility and interconnected to the Master by a network of fibre optics.

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THE DEVELOPMENT OF A FPGA BASED FRONT END SAFETY INTERLOCK SYSTEM

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Abstract

A front end (FE) safety interlock control system was designed to protect humans and the machine integrity during operation. Since stability and reliability are an important requirement in this system, we developed a FPGA based system to control a safety logic for interlock protection. The integration of the FPGA, Real-time and redundant fail-safe system in the FE interlock system enables us to provide a safe protection with EPICS communication and hardware protection functions.

INTRODUCTION

In the phase II TPS project, there are seven insertion device FEs, three bending magnet FEs, and one diagnostic FE. After the first two years of TPS operation, an event occurred when the interlock system crashed in the TPS FE05, 23, 41, and 45 [1] (see Fig. 1). As a consequence, some safety control system design faults were reviewed and modified. In order to enhance the stability of the interlock system, the original Real-time system with systematic risks was replaced by the FPGA based safety interlock system.

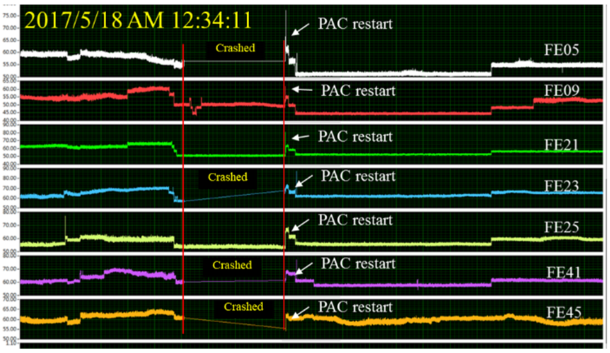

Figure 1: Record of a safety interlock controller crash (verified by CPU loading percentage).

STRUCTURE DESIGN OF THE SAFETY CONTROL SYSTEM

In the original TPS FE design, we used the National Instrument compact-RIO 9074 as the main controller for the safety interlock system and the logic program deployed in the Real-time system was operated by VxWorks. This design may cause a crash of the safety interlock system due to CPU loading or network risk [2]. In case of the TPS, the CPU loading of the cRIO 9074 was increased by using the distributed system manager (DSM) software to monitor the controller status. Due to safety concerns, the system needs to be separated into a safety logic program and a network protocol function into two independent systems. Therefore, the TPS FE interlock was upgraded from cRIO 9074 to cRIO 9030 and the logic program is now located on a field programmable gate array (FPGA) system. The Real-time system, operated by Linux, is engaged to publish the FE status by EPICS protocol. FPGA I/O nodes were created and its indicator for each corresponding share variable in the Real-time system to publish the EPICS protocol by cRIO 9030 network function. This structure means that the connection between FPGA and Real-time is a one-way transmission with no system resource concerns when the safety interlock system is operating as Fig. 2 shows. Therefore, the FPGA based safety interlock system combined with Real-time results in both stability and feasibility of safety and network function.

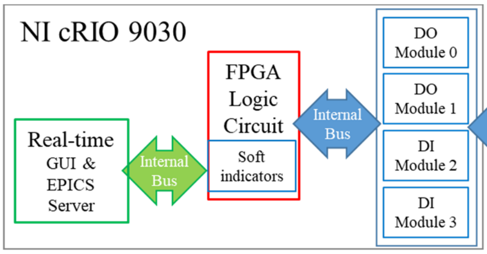

Figure 2: The structure of the FPGA based safety interlock control system.

In the TPS FE, the personal protection system (PPS) and machine protection system (MPS) were integrated into one safety controller NI cRIO 9030. Considering a fail-safe feature, a redundant system, which is controlled by a YOKOGAWA programmable logic controller (PLC) FAM3, is used to monitor the NI cRIO 9030 by hardwiring signal connections. The main controller for the safety interlock system NI cRIO 9030 and the redundant system FAM3 monitor each other by a 2 Hz heartbeat and watchdog individually. If any signal check detects a failure, the other controller will shut down the FE until FE staff resets the system manually. The control logic flow is shown in Fig. 3.

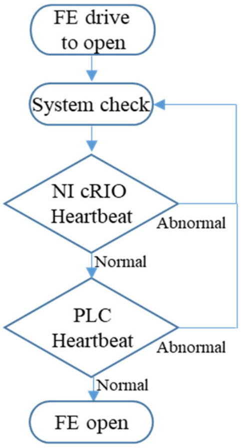

Figure 3: NI cRIO9030 and PLC FAM3 heartbeat logic checking flow.

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DEVELOPMENT of the NEW SPILL CONTROL DEVICE for J-PARC MR*

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Abstract

J-PARC Main Ring (MR) is there are two operation modes of the fast extraction (FX) and slow extraction (SX) [1,2]. The SX operation used the spill control system. It consists of two kinds of Extraction Quadrupole Magnet (EQ), Ripple Quadrupole Magnet (RQ) and Spill Control Device with Digital Signal Processor (DSP) which calculates and controls it the optimal current pattern using the monitor signal of an extraction beam. It is used to make flatten the extraction beam structure and reduce the ripple noise. The present Spill Control Device needs to be reviewed from the aspect of service life etc. In this presentation, we will focus on improving the versatility of the device and the operability of the DSP program, and explain the development of the next-generation spill control device.

INTRODUCTION

The SX of the J-PARC MR utilizes third integer resonance at Qx = 22.333 [3]. After acceleration of MR, the beam is extracted slowly by betatron tune ramping of main quadrupole magnets in the flattop period of about two seconds. By constant tune ramping speed, the spill structure of slow extraction beam is like Gaussian shape. In physics experiment, the trigger rate or the counting rate of data acquisition system is limited by the hardware and software architecture. In some cases, the detectors cannot separate multiple events, due to collisions with too many particles and the target. In other cases, the data acquisition efficiency can be bad, due to a large dead time when too much beam is extracted. Therefore, the spill beam should be flat and stable sufficiently in extraction period. In order to make flat spill structure, we control the horizontal betatron tune by using the EQ magnets via spill control system. On the other hand, the ripples of main magnet power supply affect to spill structure by spike noise. We reject the ripple noise by RQ magnet.

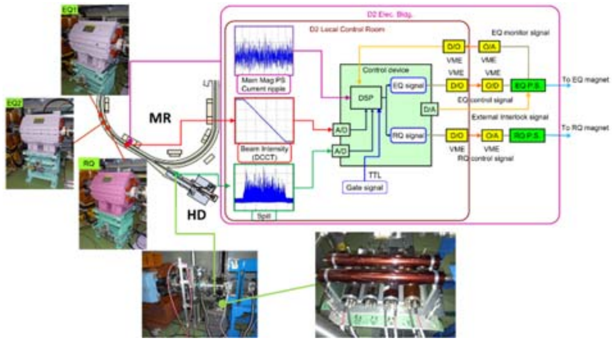

Figure 1: Signal flow of the spill control system.

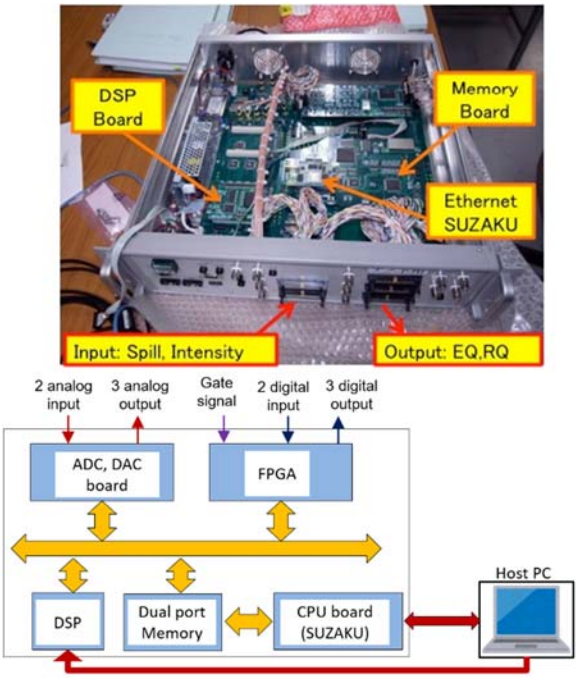

Figure 2: Spill control unit and signal flow.

SPILL CONTROL SYSTEM

Figure 1 shows the signal flow of the spill control system. The spill control unit provides control patterns to EQ and RQ power supply (PS). It is composed of circuit board for DSP, five analog/digital signal inputs, six analog/digital outputs interfaces and RS232 base serial communication interface. The circuit board consists of DSP card, dual port memories and FPGAs. Figure 2 shows the DSP spill control unit and signal flow. The DSP is in charge of spill control calculation. Dual port memory is used to connect the DSP and FPGA, and to share and read spill control calculation data. Table 1 shows the spill control unit spec. The analog input signals consist of control timing gate, residual beam intensity from DCCT and spill intensity of extracted beam from spill monitor.

Table 1: Spill Control Unit Spec

DSP board	TMS320C6713 (TEXAS INSTRUMENTS
ADC, DAC board	C6713DSK (TEXAS INSTRUMENTS)
Sampling frequency	100kHz
Analog Input/Output	±1V, 10kΩ
Digtal Input/Output	LVTTL3.3V, 32bit Positive logic

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DESIGN AND IMPLEMENTATION OF FPGA BASED PROTECTION SYSTEM FOR BEAM ACCELERATION IN LINEAR IFMIF PROTOTYPE ACCELERATOR

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Abstract

The IFMIF (International Fusion Materials Irradiation Facility) Prototype Accelerator (LIPAc) has been developed in the Engineering Validation and Engineering Design Activity (EVEDA) phase. The LIPAc is designed to produce a deuteron CW beam with a current and an energy of 125 mA and 9 MeV. After the injector campaign, the LIPAc is entering the RFQ (Radio-Frequency Quadrupole) commissioning phase in which such subsystems as the RFQ, RF system and Beam Instrumentation systems have been attached.

The LIPAc control system consists of local control systems (LCSs) and the central control system. The LCSs haven been developed by Europe and delivered with the subsystems; and the central control system, including personnel and machine protection, timing, archiving and alarming, has been developed by Japan. Japan and EU are jointly integrating them to control the whole accelerator in an organized manner.

Fabrication of the control system is made on the EPICs platform to reduce the risk in integration. Some part of the protection systems has been implemented in FPGA to satisfy both the speed and sophisticated control. The basic idea and implementation of the control system will be presented.

INTRODUCTION

The IFMIF Prototype Accelerator has been developed in the Engineering Validation and Engineering Design Activity phase. The final target of the LIPAc is to generate a heavy deuteron CW beam with a high intensity and 125 mA and an energy of 9 MeV for an average power of 1.125MW.

The control system of the LIPAc consists of six subsystems: Central Control System (CCS), Local Area Network (LAN), Personnel Protection System (PPS), Equipment Protection System (MPS), Timing System (TS), and Local Control System (LCS) of subsystems. Europe and Japan have been developing the control system jointly, in which Europe is in charge of LCSs and Japan five other systems. Upon completion of the implementation, the LIPAc is planned to be operated from the CCS and the operational parameters and experimental data can be monitored from the CCS and archived by the archive system.

After the completion of the injector campaign (Phase A), the RFQ, RF system, LLRF, MEBT and BI (beam instrumentation systems) are being attached to the injector (Fig. 1) and the development of the LIPAc has entered the RFQ commissioning phase (Phase B) [1].

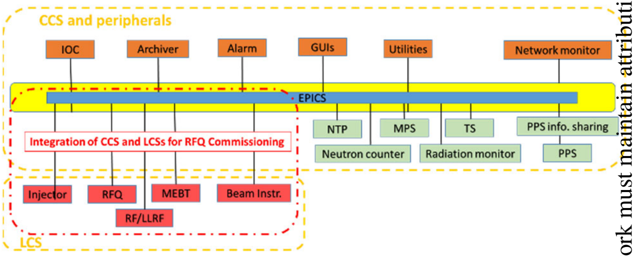

Figure 1: Control system configuration for RFQ commissioning.

PPS and MPS have an aspect of final protection scheme. Parameters such as thresholds, etc., are not supposed to be changed once they are determined. So, they are implemented basically using PLC-based technology for the general slow interlocks. For faster interlocks, such custom-made cards as those with Application-Specific Integrated Circuits (ASICs) have been needed when both speed and reliability are mandatory.

In recent years, an architecture using FPGA is frequently used to achieve both time performance and reliability with more flexibility. As the logic required some systems are more complicated, FPGA is advantageous in faster development, adaptability, reusability and therefore reduced final costs.

In such a case as IFMIF, subsystems are developed and delivered by different countries and detail specs are not fully prepared/agreed in advance, since some interlock conditions and their criteria could be complicated and likely determined from experiments. From these reasons some part of the LIPAc protection system uses an FPGA architecture.

In this workshop, the authors will present cases of such inter locks as chopper [2], beam counting and overload protection for diagnostics system used in LIPAc.

CHOPPER INTERLOCK

A chopper is used to allow interceptive diagnostics after the RFQ. Due to the high power and long rise time of the beam extracted from the ion source, pulsed mode operation is used (Fig. 2) to prevent damage on the diagnostics. A high voltage is applied to the chopper which deflects the beam usually. In response to the timing sig-

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REMOTE WAVEFORM ACCESS SUPPORTS WITH EPICS FOR TPS AND TLS CONTROL SYSTEMS

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Abstract

To eliminate long distance cabling for improving signal quality, the remote waveform access supports have been developed and applied on the TPS (Taiwan Photon Source) and TLS (Taiwan Light Source) control systems. Waveforms include pulse magnets power supplies waveforms, AC waveforms of main power supplies, LLRF waveforms, beam signals, etc., and these are necessary to be monitored during routine beam operation. One is that use the EPICS-embedded data acquisition systems which are formed by the Zynq System-on-Chip architecture to capture the waveform signals; the other is that a dedicated EPICS IOC is used to communicate with the present Ethernet-based oscilloscopes to acquire each waveform data. According to specific purposes use, the different graphical applications have been developed and integrated into the existing operation interfaces. These are convenient to observe waveform status and to analyze the acquired data on the control consoles. The efforts are described at this paper.

INTRODUCTION

TPS is a new and highly bright synchrotron light source constructed at National Synchrotron Radiation Research Center (NSRRC) in Taiwan. It consists of a 150-MeV electron linear accelerator, a booster synchrotron, a 3-GeV storage ring and experimental beam lines. Civil construction began in February 2010 and was completed in the first half of 2013. Installation and integration of the accelerator system began later in 2013. The control system environment was ready in middle of 2014 to support the testing and commissioning of the final subsystem integration without the beam. Commissioning with the beam was successful in December 2014.

TLS is a third generation of synchrotron light source built at the National Synchrotron Radiation Research Center (NSRRC) site in Taiwan, and it has been operated since 1993. The TLS consists of a 50 MeV electron Linac, a 1.5 GeV booster synchrotron, and a storage ring with 360 mA top-up injection. The TLS Control system is a proprietary design [1]. It consists of console level workstations and VME based intelligent local controller (ILC) to interface with subsystems. Hardware and software on console level workstation change several times due to evolution of fast evolution of computer technology. Due to the well design of the original control software structure, port to new Linux platform without difficult.

EPICS (Experimental Physics and Industrial Control System) is a set of open source software tools, libraries and applications developed collaboratively and used to create distributed soft real-time control systems for scientific instruments such as the particle accelerators and large scientific experiments [2].

EPICS were chosen as control system framework for the Taiwan Photon Source (TPS) of 3 GeV synchrotron light source [3]. The TPS control system with EPICS mechanism had been integrated and commissioned. On the other hand, in order to adopt update technology and re-use expertise of manpower, the upgrade and maintenance for TLS control system adopts the EPICS as its framework was decided. Moreover, some new installed subsystems runs EPICS control environment also. Mixed existed TLS control system and EPICS environment were proofed without problem

One of EPICS database records is the waveform record which stored data array acquired from the device. There are many waveforms such as signals which should be observed in synchrotron light sources including waveform variation of booster current, beam current measured by the fast current transformer, and filling pattern, RF pulse, pulse magnet current, etc. Acquiring waveform data should be based upon EPICS waveform supports. Through PV (Process Variable) channel access the client console can observe the waveform by using various toolkits (EDM, CS-Studio, MATLAB, Python, etc.). In addition, one of the benefits on EPICS waveform supports is that LXI-compliant [4] oscilloscopes with Ethernet interfaces can be adopted to be controlled remotely and users can observe the related waveform data on the control consoles easily.

Another solutions of waveforms access for some parts of subsystems are using the standalone EPICS embedded data acquisition system and the PCI-Express form factor digitizer. The standalone EPICS embedded data acquisition system is convenient to access data by EPICS PVs via Ethernet interface. The PCI-Express form factor digitizer is plugged into Linux-PC with PCI-Express slot, and the related functional libraries of device driver are necessary for building as an EPICS IOC. The efforts of implementing remote waveforms access supports with EPICS for the TPS and TLS control systems are summarized in the following paragraphs.

SYSTEM ARCHITECTURE OF WAVEFORM SUPPORTS WITH EPICS

Remote waveforms access supports with EPICS mechanism have been developed and applied on both TPS and TLS control systems. The system architecture of waveform supports is illustrated as Fig. 1. During the commissioning phase of TPS control system, the oscilloscopes have been widely adopted to monitor

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INJECTION AND EXTRACTION TIMING CONTROLS AT SuperKEKB DAMPING RING

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Abstract

SuperKEKB project aims at the world highest luminosity to 8×10^{35} cm^{-2}s^{-1}. To achieve the luminosity, a lot of equipment was newly constructed or upgraded. Especially, a Damping Ring (DR) was newly constructed at the middle of the injector linac for making lower positron emittance. The DR timing control system was also fabricated as a branch of the main SuperKEKB timing system. The synchronized timing is generated at the main timing system. It is received at DR sub-timing station and is distributed to the end of some equipment, Kicker, Septum, and monitoring devices.

We succeeded to generate not only synchronized timing but also beam control information such as beam gate for trigger inhibit signal and injection and extraction timing "value" via data buffer delivery. By using this method, accelerator operation became more convenient system.

INTRODUCTION

SuperKEKB accelerator is electron-positron collider for high-energy physics experiment [1]. Electron and positron are stored in High Energy Ring (HER) and Low Energy Ring (LER) at the energy of 7 GeV and 4 GeV, respectively. To overcome the luminosity of previous KEKB project, a Damping Ring (DR) has constructed to provide low emittance positron to LER. The specification of DR is listed in the Table 1.

Table 1: Key Parameters of Damping Ring

Parameters	Value	Unit
Energy	1.1	GeV
Repetition frequency	50	Hz
Circumference	135.5	m
RF frequency	508.9	MHz
Harmonic Number	230	
No. of bunch trains	2	
No. of bunches / train	2	

The positron beam is accelerated to 1.1 GeV in the injector linac, and delivered to the DR through beam transport line. The DR stores the positron beam during 40 ms which is an essential damping time to make low-emittance. On the other hand, since the maximum injection repetition is 50 Hz, it is necessary to simultaneously control three kinds of states of injection, extraction, and storage. However, since each state is needed to occupy different bucket, different timing information is needed. Therefore, damping ring timing system has two timing receiver for injection control and extraction control.

TIMING CONTROL AT THE DAMPING RING

Overview

The timing signal is generated and controlled at SuperKEKB main timing station at injector linac [2, 3]. The timing is distributed to all over the SuperKEKB accelerator timing receiver with the fiber-optic cables. The DR timing system is its branch of the main timing system. Figure 1 is the picture of DR timing system. It is fabricated in one VME crate, and consists of a controller, a device monitor (RAS), two timing receivers and a time to digital converter (TDC). We use MVME5500 on-board CPU controller and VxWorks-6.8.3 is working on the board. The RAS monitors power voltage and temperature, and is controlled by serial port connection. As the timing receiver, we use Event Receiver (VME-EVR-230RF) developed by Micro Research Finland [4]. The TDC is originally developed to monitor the timing whether it is generating at an appropriate timing [5].

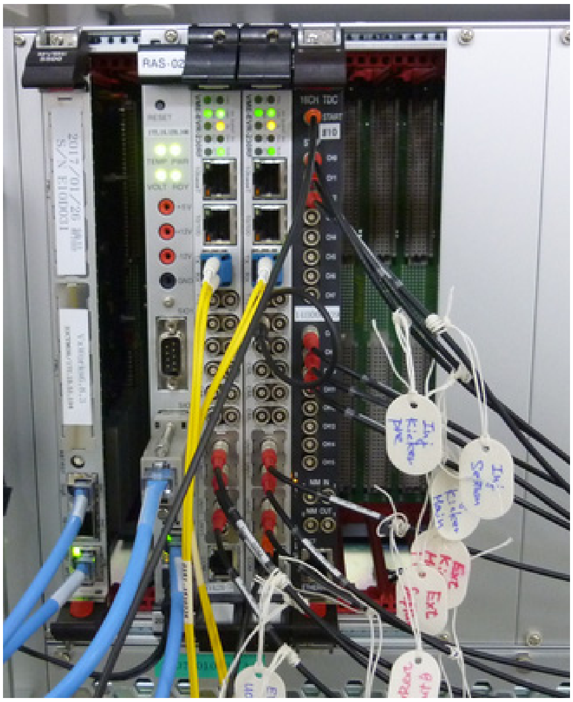

Figure 1: The picture of Damping Ring Timing System.

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OPERATIONAL EXPERIENCE OF THE DIGITAL LLRF CONTROL SYSTEM AT THE BOOSTER RING OF TAIWAN PHOTON SOURCE

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Abstract

The purpose of a Low-Level Radio Frequency (LLRF) system is to control the accelerating cavity field amplitude and phase. To have better RF field stability, precise control and high noise reduction, a digital LLRF control system based on Field Programmable Gate Arrays (FPGA) was developed at NSRRC. We replaced the analog LLRF system with a digital version for the TPS booster ring at the beginning of 2018. During routine operation of the booster RF, some faults occurred when the digital LLRF operated in the energy savings mode. The performance and operational experience of the digital LLRF for the TPS booster will be presented here.

INTRODUCTION

The Taiwan Photon Source (TPS) at the NSRRC is a third-generation light source operating at 3 GeV. The field in the accelerating cavity is controlled by a Low-Level Radio Frequency (LLRF) system. A digital LLRF (DLLRF) control system based on Field Programmable Gate Arrays (FPGA) is expected to exhibit improved RF field stability, precise control and high noise reduction. The analog LLRF system for the TPS booster ring was replaced by a digital version at the beginning of 2018 [1]. Since the digital tuner loop is not implemented yet, we only replaced the modules in the RF path for the digital system to keep the tuner function and the interlock protection system. The Programmable Logic Controller (PLC), including the analog tuner loop and the function of interlock protection, is still contained in the DLLRF system. Figure 1 shows the architecture and photos of the TPS booster DLLRF system.

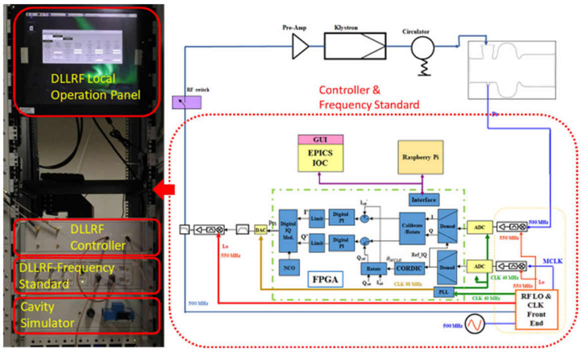

Figure 1: Architecture and photos of the TPS booster DLLRF system.

During full power routine operation with the DLLRF system, the difference between set points and measured values can be controlled to 0.32 ± 0.52 % and 0.01 ± 0.13 degrees for the cavity voltage amplitude and phase, respectively. The sidebands of the 60 Hz noise and its harmonics can be suppressed down to -70 dBc. The details of the design and implementation of the DLLRF controller, the hardware architecture, test results and operation performance of the TPS booster DLLRF system can be found in [1-3].

The operational status can be monitored by the data acquisition system, including the transient data recorder for trip analysis and the archiver for the slow long-term data recorder. Figure 2 shows the hardware structure for the TPS booster RF data acquisition system. All the analog signals are collected on the junction box and distributed to the digitizers. Signal buffers are placed between junction box and digitizers to avoid any impedance mismatch. Four digitizers are used for the EPICS IOC to collect historic data at a slow sampling rate (about 1 kHz) and one digitizer is used for the transient recorder with a sampling rate of up to 250 kHz.

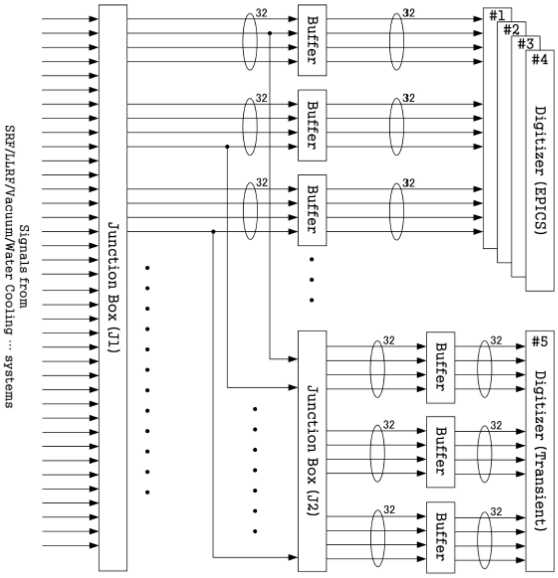

Figure 2: Hardware structure of the data acquisition system.

A function to save energy [4] is implemented in the TPS booster DLLRF by controlling the klystron cathode current and cavity voltage following the injection timing signal [5]. During routine operation, some faults occurred when the DLLRF operated in the energy saving mode. The operational experience of the DLLRF for the TPS booster as well as trip analyses are reported in the following sections.

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TIMING SYSTEM FOR MULTIPLE ACCELERATOR RINGS AT KEK e+/e- INJECTOR LINAC

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Abstract

The KEK e+/e- injector linac is operated in multiple beam modes that can be switched every 20 ms for e+/e- beam injection to five different circular accelerators, SuperKEKB High Energy Ring (HER), Photon Factory (PF) ring, PF-AR, positron damping ring (DR) and SuperKEKB Low Energy Ring (LER). Because those accelerators have different ring energies and radio frequencies, the linac is required to have a timing system which supports multiple modes and synchronization system to the circular accelerator. Those systems to fulfil multiple injections to independent circular accelerators are described in this paper.

INJECTOR LINAC

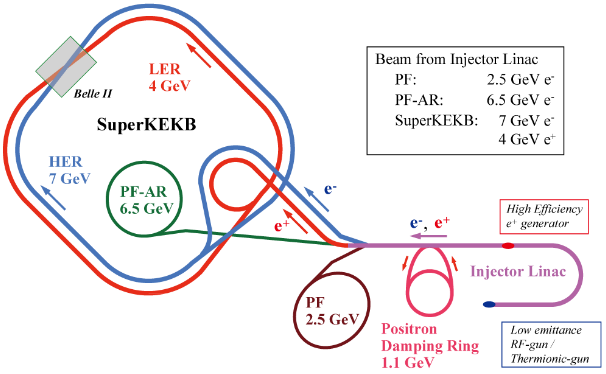

Figure 1: Schematic view of the e+/e- injector linac and accelerator rings at the KEK.

The KEK e+/e- injector linac and five different rings are depicted schematically in Fig. 1. The HER requires low emittance electron beam, thus the photocathode rf-gun [1] is used for HER beam injection. High charge (~10 nC) electron bunches for positron production and electron beams for PF, PF-AR are given by the thermionic gun. The linac consists of 8 sectors (A-C, 1-5) which have 8 high power RF units except for injector (rf-gun, thermionic gun and bunching section) and positron production section. The RF unit provides RF power to 4 accelerating structures. The beam energy at the end of the linac is controlled by RF phase of the unit. In order to set optimum beam optics for each the beam mode, 28 pulsed quadrupoles and 36 steering pulsed magnets were installed in last year [2]. Parameters such as accelerating RF phases and the currents pulsed magnets can be changed every beam pulse by employing the event timing system.

TIMING SYTEM OF THE LINAC

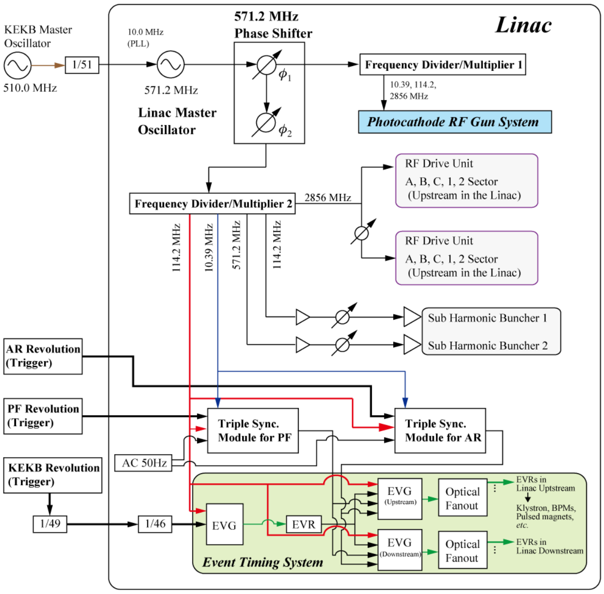

Figure 2: Timing system of the linac.

Figure 2 shows the linac timing system with the fundamental RF signals. The master frequency of 571.2 MHz is generated with a signal generator which is synchronized with the SuperKEKB oscillator via a 10 MHz reference signal [3]. The 571.2 MHz phase shifter set the linac whole RF phase according to the beam mode. The phase of ϕ_1 and ϕ_2 correspond to the HER and the LER injection phase, respectively. In case of the PF and the PF-AR injection, the ϕ_2 is set to zero. Because large phase shift accompanying beam mode change makes the laser system for the rf-gun unstable, the laser system always synchronized with the HER.

The trigger signals to various components are distributed by the MRF event system [4] which consists of event generators (EVG) and event receivers (EVR). The event timing system has three EVGs [5]. The first EVG-EVR set makes a trigger timing signal for the HER/LER injection. The trigger timing signal for the PF/PF-AR injection is sent from a special module to make a synchronized signal with the circular accelerator. The EPICS IOC program for the event system selects a corresponding trigger for 2nd EVGs of the beam mode. Then, the 2nd EVGs distribute an event code which corresponds to the beam

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STUDY OF ENERGY SAVING OPERATION FOR THE TLS BOOSTER POWER SUPPLY

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Abstract

Operating an injector of a synchrotron light source, energy efficiency is an important issue. Dipole and quadrupoles families of the booster synchrotron for Taiwan Light Source (TLS) is resonantly excited by three White circuits at 10 Hz rate. Magnet current cannot response in cycle-by-cycle basic due to resonance nature. The possibility of operation of the booster synchrotron in energy saving mode is explored. Minimizing the duration of magnet excitation without effect of the injected and extracted beam to support top-up operation for the TLS is investigated. Efforts will be presented in this report.

INTRODUCTION

The storage ring of TLS is operated in top-up injection mode at stored beam current 361 mA. Typical beam lifetime is about 6~7 hours, it needs to refill beam at every minute. The booster synchrotron is turned on continually since the top-up injection started from 2005. Energy saving operation of the booster RF system was investigated and activated [1, 2]. The possible operation scenario for the magnets excitation system is studied recently.

There are three families of magnet driven by a White circuit [3, 4, 5, 6, 7]. Each White circuit consists of a DC and an AC power supply in the TLS booster synchrotron. The DC power supply is turned on firstly before AC power supply to protect the polarized electrolyte capacitor. The control sequence is that after DC power supply achieves its nominal value then AC power supply can be enabled. The three families consisted of dipole, focusing quadrupole and defocusing quadrupole magnets. After three families of power supply turned on respectively, the phase regulation algorithm is applied to ensure the relationship between three White circuits to be in phase. The time for turning on DC, AC power supplies and applying phase regulation needs to be ended before beam trigger signal. To proceed the energy-saving of the booster synchrotron, the excitation is removed in reverse order, phase regulation stopped firstly, AC power supply turned off then DC power supply turned off at last. Minimizing the time duration during above cycle will save more electricity.

WHITE CIRCUITS OF THE BOOSTER SYNCHROTRON

There are three families of magnet systems in the booster synchrotron. These are dipole, focusing quadrupole and defocusing quadrupole magnets. Each family includes 12 magnets. The main excitation circuits are configured as three independent White circuits and resonantly excited at 10 Hz. The White circuit comprises two coupled resonant circuits, which are a bypass capacitor and a DC power supply with two resonant LC circuits. Each White circuit has the same configuration; those AC and DC power supplies work independently. Both DC and AC current are controlled within an error less than 5 x 10^{-4}. The tune variation during energy ramping should be in the order of 0.01 for stable operation which corresponding to 5 x 10^{-4} focusing error. This implies that the current of DC and AC components for quadrupole magnets must be stabilized within the same order. The amplitude and phase might be drifted which caused by resonance frequency change slightly due to ambient temperature and heating of the capacitor of White circuit. It takes several hours to achieve thermal equilibrium. The tolerable phase drift was estimated to be 0.1° corresponding to 30 μsec for 10 Hz normal operation.

The controls system needs to provide adjustable precision for amplitude and phase of 10 Hz sinusoid reference for AC power supplies of three White circuits. The block diagram of White circuit power supplies interface is illustrated in Fig. 1. The White circuit power supply control interface consists of amplitude and phase detector module, high purity 10 Hz generator and amplitude regulator module, digital delay generator (DDG), time to digital converter (TDC), interlock and protection module, 16 bits DAC and ADC module. The amplitude/phase detection module measures the peak of magnet current for the analog PID amplitude regulator of high purity 10 Hz sine-wave generator.

The major function of the White circuit power supply control includes provide 10 Hz reference signal to drive power supply and regulate amplitude and phase of the AC current of magnets [4]. The amplitude regulation loop purpose is to keep magnet current with constant amplitude. The DAC module sets the amplitude reference for the DC/AC power supply, the high purity 10 Hz sine-wave generator module is based on the amplitude reference to generate 10 Hz sine-wave for AC power supplies to control the amplitude of White circuit. Purposes of the phase regulation loop as shown in Fig. 2 is to keep constant phase difference between two quadruple families with dipole.

The operation sequence of the White circuits, three DDG module sets the phase of a 10 Hz trigger signal for three high purity 10 Hz sine-wave generator modules that produces correlated phase of the three 10 Hz sine-wave output. The DCCT device senses the output amplitude of magnet current for the amplitude/phase detection module that directly detects the output phase of magnet current then feedbacks to TDC module for the software, PID phase regulation, to rectify the phase of DDG module.

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DEVELOPMENT OF TRIGGERED SCALER TO DETECT MISS-TRIGGER

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Abstract

A "triggered scaler" has been developed for J-PARC accelerators. It is a PLC-type scaler with memory-buffers. Number of pulsed signals is counted and stored in a cell of memory-buffer, then, each external trigger (25 Hz) shifts the pointer to the cell. The buffer size (192) is designed to store one machine-cycle (2480 ms or 5200 ms in J-PARC). Demonstrative measurements using a prototype module are reported. In addition, scheme to detect miss-trigger events are discussed.

INTRODUCTION

J-PARC (Japan Proton Accelerator Research Complex) is a high-intensity proton accelerator complex. It consists of three accelerators: a) 400-MeV Linac (LI), b) 3-GeV Rapid Cycling Synchrotron (RCS), c) 30-GeV Main Ring (MR) [1-2]. Since the initial beam in 2006, beam powers for experimental facilities were steadily increased [3].

There are two time cycles in J-PARC. The rapid cycle, 25 Hz, is used at LI and RCS. The slow cycle is used at MR. In 2018, when MR delivers proton beams to Neutrino Facility (Hadron Facility), 2480 ms (5200 ms) is used, respectively. Typical timing scheme is shown in Fig. 1. Since the slow cycle determines the overall time behaviour of accelerators, it is called “Machine Cycle”.

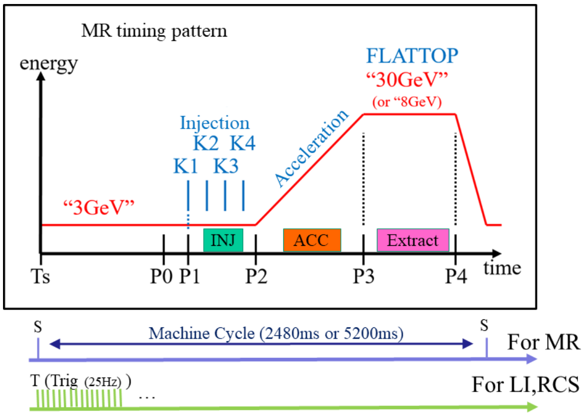

Figure 1: Typical timing scheme of J-PARC accelerators.

TIMING SYSTEM AND MISS-TRIGGERS

Overview of the Timing System

The control system for J-PARC accelerators was developed using the EPICS (Experimental Physics and Industrial Control System) toolkit [4-5]. Addition to it, we have a dedicated timing system [6].

The timing system consists of one send module and several receiver modules. Both modules were developed as home-design VME modules. Event-codes, called “types”, generated by the send module are distributed to receiver modules. A fiber-optic cable network is used for “type” distribution, using several O/E (or E/O) modules. According to the received “type”, each receiver module generates eight independent trigger signals for accelerator components. There are 118/43/45 receiver modules used in LI/RCS/MR, respectively.

Miss-trigger Troubles in J-PARC

During the operation since 2006, we have experienced a few miss-trigger troubles. Here we show three cases.

The first case started as a fault of MR kickers in February, 2014. Soon we found other MR components also miss-behaved occasionally. Finally we found that missing of the 25-Hz trigger-clock occurred in the whole MR area at the rate ~10 times per day at maximum. In May, 2014, we replaced an O/E module, which is located at the root position of MR area.

The second case appeared as a bad quality beam during stable beam delivery to Hadron Facility in November, 2016. Here “bad quality” means that beam size was slightly larger than normal, but still acceptable for experiments. Such beams appeared a few times per month [7]. Some O/E modules were replaced, but not effective. In May, 2017, we found that a receiver module for one of MR steering magnets showed momentary errors, hence, miss-triggers occurred. The timestamps of errors were retrieved from the archive system, which agreed with the timestamps of bad beams. Later survey showed that the errors were caused by external common-mode noises. We added ferrite cores to metal cables connected to the receiver module.

The third case was happen in November to December, 2017. An O/E module, which was used to send the 25-Hz trigger-clock signals from RCS to MR, started to produce fake signals (Fig. 2). Since fake signals affected a critical beam diagnostic system, accelerator operation suspended a few to 10 times in a day. We replaced the O/E module.

In the first and the third cases, it was difficult to find the troublesome module among many suspicious modules. In the second case, miss-trigger events were very rare, and it took six months to find the origin. Such experiences suggested us to develop a new module to detect a miss-trigger.

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GUARANTEEING THE MEASUREMENT ACCURACY IN Em#

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Abstract

ALBA, in collaboration with MAXIV, has developed a four-channel electrometer of 18bit deep with 8 ranges from 1mA to 100pA. The objective of accuracy in the measurements made clear from the beginning the need to compensate the components tolerances and its dependence with temperature. This paper describes the tests performed to characterize the acquisition chain, the automatic calibration developed and the hardware and software implemented to achieve the accuracy target. This implementation has been eased due to the high flexibility given by ALIN and Harmony [1] architectures used in the Em#.

EM# RETROSPECTIVE

Low current measurements are widely extended in Synchrotron light sources, like ALBA. The major need of electrometers in ALBA is for Front-Ends and Beamlines diagnostics. This need was identified during the construction of ALBA and the first version of the electrometer was designed [2]. This version was successfully installed in all ALBA beamlines and Front-Ends, but some beamlines went beyond using the electrometer as a detector. Besides the good precision achieved in the current measurements, this first version had some limitations that affected its functionality: synchronization performance, low ADC resolution, lack of calibration or temperature compensation, are some examples. In 2013, the need of a redesign a new electrometer electrometer was clear. The new instrument had to solve also a problem of obsolescence of the microprocessor board. The same year started the project of the second version of ALBA electrometer, Em# [3]. The first steps were defining an architecture which would give as much flexibility as possible and to avoid future obsolescence basing the design on standards and avoiding brand dependences. On that way, it was decided to use SPEC board from OHWR [4-5] and designed by CERN. In 2015, MaxIV Light source signed a collaboration agreement to join in Em# project. Finally, in 2016, 12 units in ALBA and 50 units in MaxIV were assembled.

ACCURACY OPTIMIZATION

One of the main targets of Em# was the improvement of its accuracy. The tests of first version of ALBA electrometer showed that the achieved precision exceeded expectations. The main reason of that precision was the Current amplifier (CA) low noise, equivalent or better than many state-of-art current amplifiers (Fig. 1). For that reason, the analogue part of electrometer was kept without including major changes. Some minor changes were optimizing the heat generation, enabling the offset correction foreseen in the first design with a DAC and the addition of temperature sensor accessible remotely.

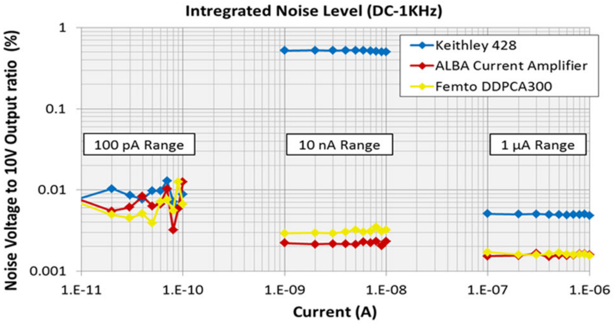

Figure 1: ALBA CA noise comparison with commercial electrometers.

One characterization showed that the noise measured in most of the ranges was so low that the ADC resolution was the limiting factor of the acquisitions. That lead to the decision of using a new the ADC with increased resolution of 18bits.

Another improvement implemented in the new Em# was the complete isolation of measurement ground respect the rest of grounds. This action minimizes the appearance of multiple ground loops which typically increase the noise of the measurements. The enhancement was not done in traditional way; it was decided to isolate the grounds after the ADC, isolating digital signals. A secondary effect of this architectural change was that it allowed measuring currents in environments were grounds needs to be biased. As this change had implications in the cost of the equipment and its auxiliary setup two versions of Em# were developed: one to work safely with HV bias (up to 1kV) and other to avoid the ground loops

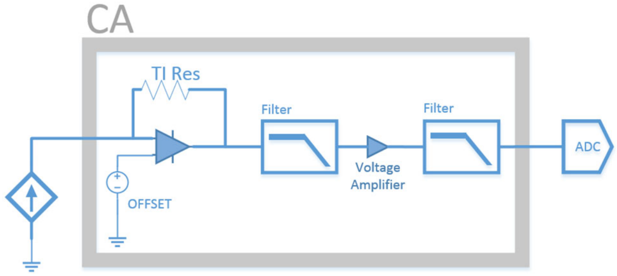

Figure 2: Schema of the CA between the current source and the ADC. The CA consists in a transimpedance amplifier with a gain, fixed by TI resistor and offset adjustment, a voltage amplifier and two low-pass filters.

COMPONENTS TOLERANCES

The first ALBA electrometer minimized the tolerances and temperature dependences in the design using matched pair resistors. However, as requirements in accuracy in-

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FURTHER IMPROVEMENTS IN POWER SUPPLY CONTROLLER TRANSIENT RECORDERS FOR POST-MORTEM ANALYSIS OF BPM ORBIT DUMPS AT PETRA-III

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Abstract

PETRA-III is a 3rd generation synchrotron light source dedicated to users with 14 beamlines beginning operations in 2010. The storage ring was modified in 2014 for an additional 12 beamlines in two extensions. It is operated with several filling modes with a total current of 100 mA at electron beam energy of 6 GeV. The horizontal beam emittance is 1.30 nmrad with 1% coupling. During a user run the Machine Protection System (MPS) may trigger an unscheduled beam dump due to high deviations in orbits if transients in the magnet power supply (PS) currents are detected which are above permissible limits. PS controllers provide transient recorder data, showing differences between current set-point and readout values in a time span of several seconds around the moment of a beam loss. We describe automatic management system handling a large number of PSs, performing automatic transient recorder data readout, storing and is available for offline analysis. We discuss hardware implementation of transient recorders and its configuration software, a Java GUI application used to investigate the transient behavior of different PSs, which might have been responsible for emittance growth, orbit fluctuations, or the beam dumps seen in a post-mortem analysis.

INTRODUCTION

PETRA-III [1] is a 3rd generation synchrotron light source commissioned with an electron beam energy of 6 GeV and 100 mA stored current at betatron tune values of 37.12 and 30.28. The horizontal beam emittance is 1.30 nmrad while a coupling of 1% amounts to a vertical emittance of 13 pmrad. The machine was commissioned for experiments at 14 beam lines with 30 end-stations in 2010. The storage ring was further modified at extensions in East and North to incorporate 12 new beam lines including a super luminescence beam line from dipole radiation in 2014. PETRA operates with several filling modes, such as 40, 60, 80, 240, 480 or 960 bunches with a beam current of 100 mA. During the normal user operation, there are unscheduled beam dumps triggered by the Machine Protection System (MPS) [2]. These triggered dumps may occur before or sometimes after the loss of beam. The reasons for beam loss due to the MPS are of course understood. But the loss of beam prior to the beam dump by the MPS or a sudden drop in beam current, are both unexpected events. In these cases the cause remains unidentified or in some cases undetected. However, although the beam is lost, it leaves its signature in its post-mortem data. These post-mortem data are huge and contain a lot of information which can be extracted and analysed in a special Java Web Application Most Effective Orbit Correction (MEOC) [3, 4]. Here we discuss how the Power Supply Controller (PSC) Transient Recorders are used in the post-mortem analysis to pin point the source of disturbance in magnet power supplies, which will help us to avoid or rectify the source of orbit perturbation in machine operation in the future.

MAGNET CONTROL SYSTEM STRUCTURE OVERVIEW

Petra III ring contains 1158 magnets, supplied by 669 power supplies. Each power supply (PS) is digitally controlled by a corresponding intelligent power supply controller (PSC), responsible for switching the PS on/off, setting the output current value in various ramping modes, monitoring the output current values and performing other PS-specific control as well as PS diagnostics functionality as shown in Fig. 1.

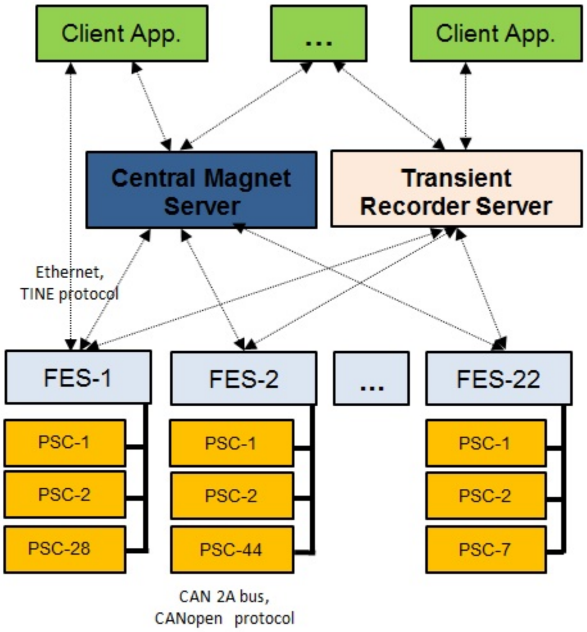

Figure 1: Magnet Control System structure overview.

All PSCs are managed by 22 front-end servers (FES) over 40 CAN buses [5] using CANopen [6-8] protocol. The Central Magnet Server communicates with front-end servers over Ethernet, using TINE [9] protocol and plays a role of the system integration unit and managing PSC group operations. It offers client applications a hardware and bus topology independent view, by hiding device hardware, addressing and fieldbus details.

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NEW COLLABORATIVE APPROACH TO SCIENTIFIC DATA MANAGEMENT WITH NOVA

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Abstract

Accelerator physics studies at the storage ring KARA at KIT produce terabytes of diagnostics data per day, which is recorded once and then reused on a long-term basis to answer different research questions at KIT. Finally, raw data and intermediate analysis results should be published along with scientific results. Thus storing from the very beginning the data of all analysis steps and its metadata in a central portal would be very beneficial. Similar requirements exist for synchrotron X-ray micro tomography at the KIT imaging cluster and there is an interest to share the large data analysis effort. By using a new collaborative approach, the NOVA project aims to create tools, to enable an efficient use of valuable beam time. For micro tomography beamlines the project will build up a comprehensive database of various demonstrator organisms for the morphological analysis of animals. The NOVA portal is integrated in the local data handling procedures and the datasets automatically appear in the NOVA portal as they are recorded. For both applications, accelerator diagnostics and X-ray tomography, the NOVA portal will offer new collaborative tools to enable synergetic data analysis.

INTRODUCTION

Scientific data management is becoming increasingly important for large scale physics facilities. The European Commission points out already in 2016 that e-science is essential to meet the challenges of the 21st century in scientific discovery and learning [1]. The emerging question is: Is your data useful for somebody in 10 years? Experiments nowadays produce data at extremely high rates, which are put high demands to the whole data acquisition chain with respect to data analysis, curation, storage and usages. While the first two steps are naturally in the focus of the scientists, the later steps are often not handled with the same effort. However, the basics of the data lifecycle must be considered as early as possible so that curated data sets with high-quality content are stored. The experimental boundary conditions must be described in form of metadata as completely as possible in order to be able to analyze data later and reuse it interdisciplinary. For providing open access to these data, the FAIR data principles, as introduced by Wilkinson et al. [2], are important. Data have to be **F**indable, **A**ccessible, **I**nteroperable and **R**eusable. To be findable, data should have a globally unique and eternally persistent identifier. To be accessible, also (meta)data have to be online. For being accessible, (meta)data have to be retrievable by their identifier using a standardized open, free and platform independent protocol, e.g. a public repository. To be interoperable, (meta)data use a formal, accessible, shared, and broadly applicable language for knowledge representation. To be reusable, metadata have a plurality of accurate and relevant attributes and should be published together with a clear and accessible data usage license.

Detectors with high temporal and spatial resolution are nowadays available and used in an increasing number of experiments. The resulting data rates are faster growing than data handling technologies. Thus, we move to an era where data becomes to large to copy and more and more scientists in smaller organizations are excluded from latest technologies. During the last ten years several large effort has been taken to find solutions for improved analysis, management and access to large data sets. Synchrotron X-ray tomography has served as an example for imaging applications in general. The integration of online data processing in DAQ systems is essential for high data rate applications. It improves the quality of recorded data and enables advanced experimental control. For the demonstrator application X-ray tomography, a suite of modular software components, called the UFO GPU computing platform, has been designed and implemented. It is intended to execute complex beamline protocols, including real-time data investigation and on-site data processing [3–6]. New methods are added to enhance reconstruction quality and to compute acceptable reconstructions from few data [7, 8]. To manage scientific data at all processing levels, we started the NOVA project. In NOVA, the Network for Online Visualization and Synergistic Analysis, a group of X-ray experts, engineers, computer scientists, mathematicians and biologists teams up to advance analysis tools for tomographic data. The project aims for synergistic data analysis and is building up a comprehensive data portal for morphologic images of small insects [9, 10].

The instrumentation in accelerator physics is currently undergoing a dramatic change. With the new instruments KAPTURE and KALYPSO developed at KIT continuous monitoring of electron beams is possible [11]. These tools uncover phenomena in elctron bunch dynamics and enable advanced beam control [12]. Similar to the imaging applications mentioned before multidimensional datasets with sizes up to the Terabyte level are recorded. Common to all this high rate and high resolution measurements is the need to describe datasets carefully and to provide hierarchical exploration of these datasets. Due to the size of the datasets, storage is costly and access is complex and time consuming.

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DEVELOPMENT OF A TASK-ORIENTED CHATBOT APPLICATION FOR MONITORING TAIWAN PHOTON SOURCE FRONT-END SYSTEM

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Abstract

In this study, we propose a task-oriented chatbot application as an interactive user interface for monitoring Taiwan Photon Source front-end system. This application can get specific information faster and improve the efficiency of the maintenance engineer's definition of fault information when a fault occurs. The chatbot uses LINE's Message API to provide services, and obtains information and status of the front-end system over EPICS protocol, responding to users' needs, like a virtual assistant. At present, the application can obtain the front-end system information already in operation of Taiwan Photon Source, including x-ray beam position monitor, safety interlock system, front-end valve status, vacuum status, etc. However, in addition to the passive provision of information, this program has a fault warning function, and will actively transmit fault information to relevant personnel when a problem occurs in the safety interlock system.

INTRODUCTION

The chatbot application is a dialogue system. Unlike a GUI system that provides a lot of information, the dialogue system is search-based. When the user asks for information, the dialogue system returns the answer. In this study, we propose a chatbot application for monitoring Taiwan Photon Source(TPS) front-end system. This chatbot will make engineer and scientist get TPS front-end status easier and improve work efficiency.

The chatbot application is based on LINE message platform. LINE is a cross-platform communication software that can be easily used on mobile phones, tablets, and personal computers. LINE provides "LINE Message API" [1] with a complete development solution, allowing developers only need to develop once and users can use this application on different platforms. This app has two main functions, one is to reply to the user query and the other is the active fault alert. The reply function is when the server receives the user query, service will use the rule-based engine to filter out the keyword, then uses "Experimental Physics and Industrial Control System"(EPICS) [2] call the associated EPICS process variable to get status information and finally passes the results back to the user. This service also continuously monitors the status of the system. When a failure is detected, it will actively send messages to the responsible personnel of the system.

CHATBOT ARCHITECTURE

The chatbot architecture is shown in Figure 1. We applied to LINE for a channel to implement this chatbot application, this channel like a friend in a social network, users just add this channel as a friend and can use it. The chatbot application is all made by Python, the LINE message API is used to connect to the LINE channel and use the push and reply methods to make fault alerts and reply to the status results queried by the user.

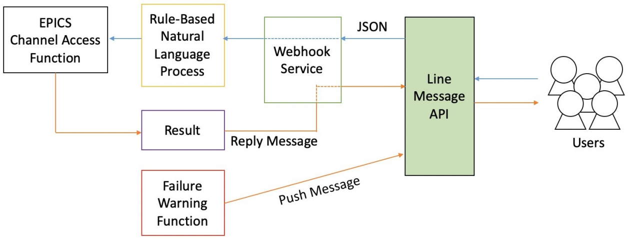
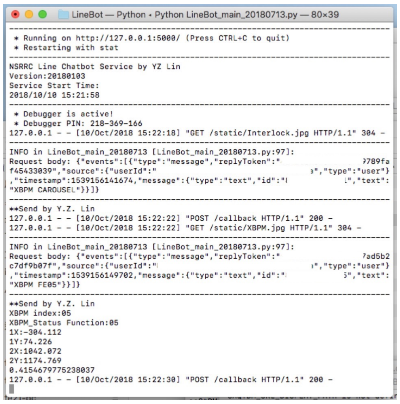


Figure 1: Chatbot architecture.

Reply Function

The Reply function has three parts: Webhook Service, Rule-Based Natural Language Process Engine and EPICS Channel Access Function.

Webhook Service is a HTTP server [3]. To implement this service, python and the flask web framework [4] is used. When a user sends a message to the chatbot, webhook service will receive a JSON file from LINE message API, this JSON file include message information, event source and time. The screenshot of the server operation is shown in the Figure 2.



```
--------------------------------------------------------------------------------
 * Running on http://127.0.0.1:5000/ (Press CTRL+C to quit)
 * Restarting with stat
--------------------------------------------------------------------------------
NSRRC Line Chatbot Service by YZ Lin
Version:20180103
Service Start Time:
2018/10/10 15:21:58
--------------------------------------------------------------------------------
 * Debugger is active!
 * Debugger PIN: 218-369-166
127.0.0.1 - - [10/Oct/2018 15:22:18] "GET /static/Interlock.jpg HTTP/1.1" 304 -
--------------------------------------------------------------------------------
INFO in LineBot_main_20180713 [LineBot_main_20180713.py:97]:
Request body: {"events":[{"type":"message","replyToken":"[redacted]789fa
f45433039","source":{"userId":"[redacted]","type":"user"}
,"timestamp":1539156141674,"message":{"type":"text","id":"[redacted]","text":
"XBPM CAROUSEL"}}]}
--------------------------------------------------------------------------------
**Send by Y.Z. Lin
127.0.0.1 - - [10/Oct/2018 15:22:22] "POST /callback HTTP/1.1" 200 -
127.0.0.1 - - [10/Oct/2018 15:22:22] "GET /static/XBPM.jpg HTTP/1.1" 304 -
--------------------------------------------------------------------------------
INFO in LineBot_main_20180713 [LineBot_main_20180713.py:97]:
Request body: {"events":[{"type":"message","replyToken":"[redacted]ad5b2
c7df9b07f","source":{"userId":"[redacted]","type":"user"}
,"timestamp":1539156149702,"message":{"type":"text","id":"[redacted]","text":
"XBPM FE05"}}]}
--------------------------------------------------------------------------------
**Send by Y.Z. Lin
XBPM index:05
XBPM_Status Function:05
1X:-304.112
1Y:74.226
2X:1042.072
2Y:1174.769
0.4154679775238037
127.0.0.1 - - [10/Oct/2018 15:22:30] "POST /callback HTTP/1.1" 200 -
```

Figure 2: Screen shot of the webhook service operation.

After receiving the message, the Rule-Based Natural Language Process Engine will filter out the keywords in the

---

* lin.yz@nsrrc.org.tw

DATA ACQUISITION SYSTEM FOR ELI BEAMLINES

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Abstract

The ELI Beamlines facility is a Petawatt laser facility in the final construction and commissioning phase in Czech Republic. In fully operation phase, four lasers will be used to control beamlines in six experimental halls.

In this paper we describe the ultrafast and distributed data acquisition system of the facility. First, we discuss the requirements and demands on the system and introduce the environment. Then we discuss the structural divide in top- and low-level system. The unique idea of this system is the extensive fibre-based low-latency communication infrastructure, which distributes large RAM buffers and allows to offload computational tasks with high throughput and real-time capability.

INTRODUCTION

ELI Beamlines [1] is an emerging high-energy, high-repetition rate laser facility located in Prague, Czech Republic. Four laser sources will supply six experimental halls, which provide various secondary sources to users. Facility commissioning, and installation work of lasers and experiments is progressing, and first enabling experiments are in progress (2018).

The general architecture of the control / DAQ system is introduced in [2]. This paper will specifically discuss the implementation of the DAQ system.

ENVIRONMENT & INFRASTRUCTURE

The core idea of the facility (multiple laser sources distributed to multiple beamlines over a sophisticated beam distribution system) creates certain conditions for the data acquisition system that are similar, but not equal to classical accelerator facilities:

- The data sources produce bunches of data based on the repetition rate of the driving lasers. Most common are single-shot, 10Hz and 1kHz. There can be more than one laser per experiment, and they are not yet synchronized.
- Characteristic data sources are based on very short pulses (femtoseconds) – requiring high sampling rates. Some lasers are operating with high repetition rates and need to be imaged pulse-by-pulse with cameras and other 2D-datactors.
- The data sources are spatially distributed of 100s of meters and located in various, sometimes challenging or hazardous environments (ionized radiation, EMP, high-vacuum, laser, bio / chemical hazards, cleanrooms up to ISO5).
- Lasers and secondary sources are all developed by different stakeholders (ranging from inhouse research groups, industrial partners – from KMEs to major corporations, national labs, partnering academic labs.). This leads to a heterogeneous environment.
- There are hundreds of cameras, tens of digitizers, and tens of specialized detectors and instruments managed by different stakeholders. While there are efforts to standardize interfaces (for example, for cameras [3]), we still see a wide diversity of interfaces.

The DAQ system has the following tasks:

- Acquisition of data and standardization for further processing and storage.
- Buffering and provision of data for further control tasks (feedback loops etc)
- Data processing (online / offline)

The system also has to provide connections for data storage and integrate the electronic timing system. Facility-wide timestamping and synchronization is a challenge because the “heartbeat” of the facility are multiple, currently unsynchronized laser oscillators using different timing systems. Our solution for electronic timing is based on WhiteRabbit [4] and currently being implemented as described in [2].

STRUCTURAL OVERVIEW

The structure of control and data acquisition system is shown on Fig. 1. This figure identifies the basic room layout relevant to the system, namely main control room, dedicated server room, laser halls, experimental halls, and plant / infrastructure rooms (which are not integrated into the DAQ system, but may receive control feedback).

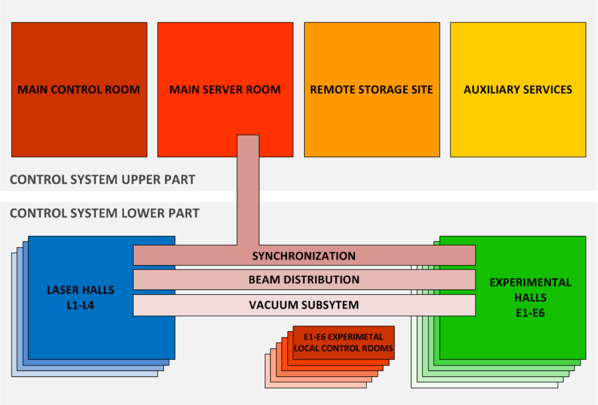

Figure 1: Structural overview.

LOGICAL OVERVIEW

The data acquisition system is divided into two levels, shown in Fig. 2 below:

- **Top level DAQ system**: This system, located in the server room, is responsible for the aggregation and buffering of large amounts of data. It also provides

DESIGN AND CONSTRUCTION OF THE DATA WAREHOUSE BASED ON HADOOP ECOSYSTEM AT HLS-II*

Y. Song, X. Chen, C. Li, K. Xuan, J. Wang, G. Liu†, NSRL, USTC, Hefei, Anhui 230029, China

Abstract

A data warehouse based on Hadoop ecosystem is designed and constructed for Hefei Light Source II (HLS-II). The ETL program based on Spark migrates data to HDFS from RDB Channel Archiver and the EPICS Archiver Appliance continuously and store them in Parquet format. The distributed data analysis engine based on Impala greatly improves the performance of data retrieval and reduces the response time of queries. In this paper, we will describe our efforts and experience to use various open sources software and tools to effectively manage the big data. We will also report the plans on this data warehouse in the future.

INTRODUCTION

The Hefei Light Source (HLS) at National Synchrotron Radiation Laboratory is the first dedicated synchrotron radiation facility in China, which provides radiations from IR to vacuum ultraviole (VUV) for various user programs. HLS was upgraded from 2010 to 2015 to improve its performance. The upgraded light source is renamed as Hefei Light Source II (HLS-II) [1]. It is comprised of an 800MeV linac, an 800MeV storage ring and a transport line connecting the linac and the storage ring. The HLS-II was fully open to users in January 2016. The control system of HLS-II is a distributed system based on Experimental Physics and Industrial Control System (EPICS) [2].

With the continuous upgrade, a series of data archiving tools has been used in HLS-II supported by the EPICS community, such as Channel Archiver, RDB Channel Archiver and the EPICS Archiver Appliance. As more and more data have been stored, the exciting data archiving tools can not meet our requirements of data query and processing. In order to deal with these problems, we are designing and constructing the data warehouse based on Apache Hadoop ecosystem. In addition, our laboratory is conducting pre-research on Hefei Advanced Light Source (HALS) project [3]. Compared to HLS-II, HALS is a larger and more complex synchrotron facility. The work described in this paper also provides technical verification for the future construction of HALS.

This paper will describe our efforts and experience to use various open sources software and tools to manage the big data effectively. We will also report the plans on the data warehouse in the future.

HADOOP ECOSYSTEM AND DATA WAREHOUSE

Hadoop Ecosystem

Apache Hadoop is a collection of open-source software utilities that facilitate using a network of many computers to slove problem involving massive amounts of data and computation. It provides a software framework for distributed storage and processing of big data [4]. As shown in Figure 1, Hadoop core components include HDFS, Yarn and MapReduce, as well as some open source projects based on Hadoop, including Spark and Impala, which provide necessary support for the whole life cycle of big data processing. Our warehouse system mainly uses the following components:

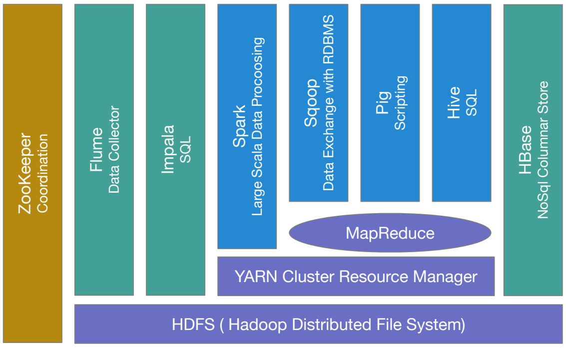

Figure 1: Hadoop Ecosystem.

HDFS HDFS is a distributed file-system that stores data on commodity machines, providing very high aggregate bandwidth across the cluster.

Spark Spark has the advantages of Hadoop MapReduce, but unlike MapReduce, its intermediate output can be stored in memory, instead of the HDFS. Tests have shown that Spark is more efficient than MapReduce for the same operation. Spark is widely used in the field of ETL (Extract-Transform-Load) and machine learning [5].

Impala Impala is an open source new query system that can query PB-level big data stored in Hadoop's HDFS and HBase. Compared to MapReduce, Impala provides data query function more efficient and convenient.

Sqoop Sqoop is command-line interface application for transferring data between relational databases and Hadoop.

Hadoop Configuration

Because the Hadoop ecosystem contains a variety of software, it is difficult to handle version compatibility and config-

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THE APPLICATION FOR FAULT DIAGNOSIS AND PREDICTION OF POWER SYPPLY CONTROL DEVICE ON BEPCII

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Abstract

With the widely adoption of complex electronic devices and microcircuits in accelerator system, the probability of system failure and functional failure will be enlarged. For example, the fault of the magnet power supply front-end electronics devices may cause accelerator energy instability and even lead to beam loss. Therefore, it is very necessary to diagnose and locate the device fault accurately and rapidly, that will induce the high cost of the accelerator operation. Faults diagnosis and prediction can not only improve the safety and reliability of the equipment, but also effectively reduce the equipment's cycle costing. We applied the FMECA and testability modelling method for the PSI device, which using in BEPCII power supply control system, and evaluated the remaining life of the PSI under certain temperature and humidity condition based on the reliability model and accelerated life test.

INTRODUCTION

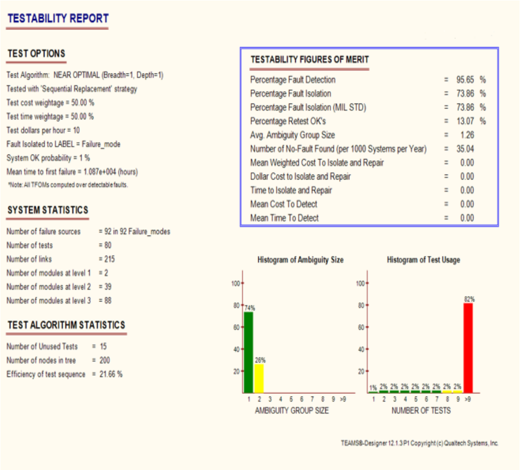
The complex electronic devices and microcircuits used in accelerator system is often the first part of the system to fail and lead to shorter service life of equipment or higher cost of system maintenance and operation steadily. In the Beijing Electron Positron Collider (BEPCII), hundreds of magnet power supplies are installed to provide power for various types of electromagnets, and the current of the power supply can be adjusted to change the magnetic field and thus control the orbit of particles. During the operation of the accelerator, failure of massive electronic devices may cause the accelerator energy to be unstable and even cause beam loss.

The traditional method to solve these problems is the fault diagnosis technology. However, fault diagnosis is generally only applied to the current fault status of the equipment. That is, the type and location of the fault are analyzed and diagnosed after the equipment fails, and cannot be pre-warned before the failure occurs. Besides, the cause of the failure of the electronic system is usually the combination of multiple failure modes and environmental stress. In actual, the issue of how to monitor the working status of electronic equipment in real time and provide early warning of possible faults is of great importance to improve the stable and reliable operation of the entire accelerator system.

TESTBILITY MODELLING

The testability modelling is a method to analyze the failure related information of equipment, which include two part at least. One is the Failure modes, effects, and criticality analysis(FMECA), that is a methodology to identify and analyze a product or process in order to determine all possible failure modes of various components in the system, how these failures affect the system, and what measures can be taken to avoid failures occurrence or reduction of the impact of a fault on the system [1]. In general, the method is to identify early in the product or process design all manner of failures so they can be eliminated or their impact reduced through redesign at the earliest possible time.

The other is testability modelling based on multi-signal flow graph [2], which combines the available test point configurations by analyzing the failure modes of each component in the system and the causes and effects of each failure mode. The Dependency Matrix D=[d_{ij}] ($1 \leq i \leq m, 1 \leq j \leq n$, where m and n denotes the totality of the source of failure and the set of testing respectively) of whole device was established, and the Fault diagnosis is to find the candidate set of faults [3] based on the structure of multi-signal model. The testability modelling report is shown in Fig. 1. Because of the reliability of the constituent units is not same in practice system, it is necessary to ament the fault probability. There are two methods that can be used when correcting, Probabilistic Equalization Method and Probabilistic Priority Method. The Probabilistic Priority method is including the failure mode more comprehensively, and the obtained analysis result is better than the Probabilistic Equalization Method.



```
TESTABILITY REPORT

TEST OPTIONS
Test Algorithm:  NEAR OPTIMAL (Breadth=1, Depth=1)
Tested with 'Sequential Replacement' strategy
Test cost weightage = 50.00 %
Test time weightage = 50.00 %
Test dollars per hour = 10
Fault Isolated to LABEL = Failure_mode
System OK probability = 1 %
Mean time to first failure = 1.087e+004 (hours)
*Note: All TFOMs computed over detectable faults.

SYSTEM STATISTICS
Number of failure sources      = 92 in 92 Failure_modes
Number of tests                = 80
Number of links                = 215
Number of modules at level 1   = 2
Number of modules at level 2   = 39
Number of modules at level 3   = 88

TEST ALGORITHM STATISTICS
Number of Unused Tests        =  15
Number of nodes in tree       =  200
Efficiency of test sequence   =  21.66 %

TESTABILITY FIGURES OF MERIT
Percentage Fault Detection                                =  95.65  %
Percentage Fault Isolation                                =  73.86  %
Percentage Fault Isolation (MIL STD)                      =  73.86  %
Percentage Retest OK's                                    =  13.07  %
Avg. Ambiguity Group Size                                 =   1.26
Number of No-Fault Found (per 1000 Systems per Year)      =  35.04
Mean Weighted Cost To Isolate and Repair                  =   0.00
Dollar Cost to Isolate and Repair                         =   0.00
Time to Isolate and Repair                                =   0.00
Mean Cost To Detect                                       =   0.00
Mean Time To Detect                                       =   0.00

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Figure 1: The testability report of power supply interface.

FAILURE PHYSICAL SIMULATION

Reliability Simulation, which based on Physics of Failure [4], is a reliability theory for establishing the relationship between failure and environmental stress from mechanism. Because of Temperature and vibration are the main factors that affect the reliability of electronic products, so

FPGA BASED IMAGE PROCESSING SYSTEM FOR ELECTRON BEAM WELDING FACILITY*

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Abstract

Automated electron beam welding (EBW) facilities require real-time control systems. EBW facility at BINP has recently renewed its control unit. High-level part of control system runs as Linux user-space application written in Erlang, while real-time subsystem runs on Field Programmable Gate Array (FPGA) for signal processing and welding control. Time-sensitive algorithms such as joint finder algorithm and pipelined data filters implemented in VHDL and dataflow DSL language Caph. DSL eases implementation and testing of algorithms and translates code efficiently to HDL. Control system filters noise and calculates a joint location for weld autocorrection within 2 µs.

INTRODUCTION

Budker Institute of Nuclear Physics has production of electron beam welding facilities (EBW) for low series production (such as manufacturing of vacuum chambers for FAIR project [1]) and for materials experiments such making hafnium carbide [2]. The largest of all facilities built has cylindrical vacuum chamber 3.5 m long and 0.98 m diameter, it has a coordinate table inside with achie-vable area of 1970×300 mm. Electron gun's acceleration voltage is 60 kV and power of its beam is up to 60 kW. It has two fore-vacuum pumps and three turbomolecular pumps. The emitter is directly heated tantalum cathode and the magnetic coordinate system has two pairs of correctors, that can deflect the beam in two dimensions. Secondary emission electrode is located below electron gun and could be used for constructing of a height map of sample welded or as a joint finder.

Foundation of the control system is a commercially available single board computer DE1-SoC. On board is Intel Cyclon V system on chip (SoC) with dual-core ARM processor and field gate programmable array (FPGA), 1 Gb RAM, ADC, Ethernet, USB. Having standard ARM processor on board allows to easily reuse thousands of open source software packages ported to ARM architecture including operating system, programming languages build tools, message brokers.

FPGA can process data in parallel – different subsystems run simultaneously, each of subsystems constructs a pipeline. Thus, the time needed for data processing (and react to inputs) is the largest of pipeline latencies, which is fixed and could be easily calculated. FPGA's generally have 20-300 K of logic elements, 1-12 Mb of memory blocks, 25-300 DSP blocks which altogether allow implementation of complex real-time algorithms.

High-level control system part is written in Erlang functional language that has a number of features that ease implementation of the control system [3]. It has language concepts for binary data decomposition. And actor-model parallelism allows to write loosely coupled finite state machines. Erlang ships OTP templates library, that features patterns such as FSM and process monitors.

Although DE1-SoC is great in many aspects, it has limitations too. It doesn't have SATA connectors, so only possible options for storage are microSD and USB drives. It has VGA port, but its connected using FPGA fabric, so having user interface on system would take extra FPGA space. Memory and calculation intensive algorithms are not suited well for CPU processors as well as FPGA. To mitigate these limitations, we implemented "thin" client on regular desktop machine, that connects to control system that is able to store data and build surface heights approximation for the operator. Interface is built with ElectronJS framework and uses React for UI widgets and logic.

IMAGE ACQUISITION

EBW facility is able to weld long titanium, aluminum or steel samples. Electronic gun is stationary so coordinate table moves the sample. Having surface height map, operator enters sequence of coordinates and parameter values at key points such as current of heater, corrector coils or anode. To weld a joint operator needs to set two or more points on sample. Then control system sets high current on cathode heater, starts to move sample according to entered sequence and in case of long sample welding corrects deviation of joint position from program.

Figure 1 shows a block scheme of hardware setup. Between electronic gun and coordinate table we have a magnetic system, that is able to deflect the beam. To construct the surface map of the sample under the electron gun, user turns on electron beam with low heater current, then Erlang control system programs FPGA to repeatedly write periodic waveform signal to magnetic system. Magnetic system has corrector coils that deflect the beam in two dimensions. Electrons hit the surface and scatter. Fraction of reflected electrons hit secondary emission electrode. FPGA system synchronizes data from coordinate table, secondary emission electrode and deflection angle that was written into magnetic system. The principle is the same as in electron microscopes (but with much higher beam intensity and subsequently noises). FPGA preprocesses image scan lines with pipelined algorithms to reduce a noise. Prepared data is passed into joint finder FPGA [4] submodule that calculates joint position in the same units as magnetic deflection angle.

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CONTINUOUS BEAM SCANNING INTENSITY CONTROL OF A MEDICAL PROTON ACCELERATOR USING A SIMULINK GENERATED FPGA GAIN SCHEDULED CONTROLLER

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Abstract

At the Center for Proton Therapy at the Paul Scherrer Institute cancer patients are treated with a fixed beamline and in two gantries for ocular and non-ocular malignancies. The gantries use a step-and-shoot technique to deliver dose covering the treatment volume with a grid of weighted proton bunches with different energies. Dose delivery for tumours moving under respiration is however challenging and not routinely performed, because of the interplay between patient and beam motions. At the Gantry 2 treatment unit, we are implementing a novel continuous beam modulation concept called line scanning, aiming at realizing a faster dose delivery to allow for effective organ motion mitigation techniques such as rescanning, gating or breath-hold. The beam current should stabilise within 100 µs, which is challenging due to the non-linearity of the system and latency of the dose monitors. In this work we implemented a gain scheduled controller and a predictor by modelling the accelerator in Simulink and developing a controller using the frequency domain robust method. We used Mathwork's HDL Coder functionality to generate VHDL code that was implemented in an FPGA in the gantry control system. Latency, overshoot and dosimetry performance improved considerably compared to a classic PID controller.

INTRODUCTION

At the center for Proton Therapy in PSI we are treating cancer patients using spot scanning techniques since 1996 [1], which opened the possibility for advanced tumour treatments with protons [2, 3]. In order to push technology forward and open the possibility to treat additional sites (moving tumours like liver and lung), we are developing in our Gantry 2 a new beam delivery modality: continuous line scanning of tumours [4]. Such a technique requires controlling the intensity of the proton beam with a high precision at the 1% level, especially during fast changes, expected to happen on a sub-ms time scale.

The facility generates the proton beam with a 230 MeV superconducting cyclotron, jointly developed between PSI and the company Accel [5].The intensity of the proton beam can be modulated near at the center of the cyclotron using two vertical deflector plates (VD) that can select how much of the beam can pass through a set of collimator slits by applying a transversal electric field [6]. In this way the radiation activation of the accelerator is minimized, as only the desired amount of protons gets accelerated to the nominal energy.

The electric field of the VD is driven by a high voltage power supply. The treatment delivery system (TDS) of the gantry can control the beam intensity by sending the appropriate voltage set point to this power supply. The intensity of the beam that is delivered to the patient is measured with an ionization chamber monitor located at the nozzle of the gantry. Figure 1 shows the accelerator and the irradiation of a patient in Gantry 2.

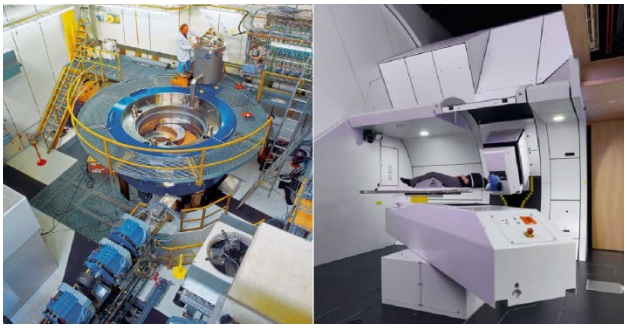

Figure 1: Cyclotron accelerator and Gantry 2, where the patients get treated with the proton beam.

For traditional spot scanning, being dose driven, the requirements for beam intensity control are not strict. However, the beam settling time and stability are crucial for a time driven delivery. In Table 1 we present the requirements for the vertical deflector voltage that were derived from the dosimetry quality required for a line scanning patient dose delivery.

Table 1 Requirements for VD Driving Voltage

Requirement	Value
Reach set point	50 µs
Remain stable (within 10V) of set point	100 µs
Voltage ripple	+-5 V
Maximum overshoot	10 V
Full range	0-5000V

A first attempt of using a traditional PID controller in the TDS to regulate the beam intensity was used as a proof of concept [7] but precision and reproducibility were still far from clinically usable. System latency, power supply hardware limitations and variability of the accelerator behaviour are the main challenges which we had to address with a novel design.

In this article we will present how we overcame the limitations of the beam current regulation system of the accelerator by characterizing the plant over more than a year, modelling it with Matlab and generating a gain scheduled controller using Simulink's HDL coder that was then implemented in the TDS on an FPGA.

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CERN SUPERVISION, CONTROL AND DATA ACQUISITION SYSTEM FOR RADIATION AND ENVIRONMENTAL PROTECTION

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Alexandru Savulescu, Bartlomiej Styczen, Daniel Vasques Ribeira
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Abstract

The CERN Health, Safety and Environment Unit is mandated to provide a Radiation and Environment Supervision, Control and Data Acquisition system for all CERN accelerators, experiments as well as the environment.

The operation and maintenance of the previous CERN radiation and environment supervisory systems showed some limitations in terms of flexibility and scalability.

In order to face the increasing demand for radiation protection and continuously assess both conventional and radiological impacts on the environment, CERN developed and deployed a new supervisory system, called REMUS - Radiation and Environment Monitoring Unified Supervision.

REMUS design and development focused on these desired features. REMUS interfaces with 75 device types, providing about 3,000 measurement channels (approximately 600,000 tags) at the time of writing.

This paper describes the architecture of the system, as well as the innovative design that was adopted in order to face the challenges of heterogeneous equipment interfacing, diversity of end users and continuous operation.

INTRODUCTION

CERN HSE Unit is in charge of providing Radiation Protection and Environmental Impact Monitoring to CERN facilities and immediate surroundings. This constant surveillance ensures:

- Workplace safety for CERN personnel and external visitors.
- Quick and appropriate response to any unplanned release of potential pollutants or ionizing radiation.
- Reporting to the authorities the nature and the quantities of emitted ionizing radiation.
- Reporting to the authorities of any release of potential pollutants.

In order to fulfil these missions, CERN has set up numerous and diverse monitoring equipment across the organization and its surroundings.

In addition, CERN HSE Unit provides a Supervision, Control And Data Acquisition (SCADA) system able to gather remotely all the relevant data in the domains of Radiation Protection and Environmental Impact Monitoring.

Between 2005 and 2016, HSE operated a supervisory system named RAMSES (RAdiation Monitoring System for the Environment and Safety) [1], which was in charge of the data acquisition, control/command and supervision of 50 device types, allowing the remote supervision of 1,500 channels.

This system allowed, for the first time at CERN, to supervise the majority of HSE relevant equipment in a consistent manner. However, it had some limitations in terms of scalability and evolutivity, making it unsuitable for longer-term use. For instance, some monitoring equipment were not remotely supervised, due to the high cost of interfacing them through the supervision. Some others where remotely controlled by proprietary supervisors, such as Berthold MEVIS, which constrained final users to use different software to operate them.

In 2012, HSE started the development of a new supervisory system, REMUS (Radiation and Environment Monitoring Unified Supervision) that would tackle those limitations. In particular, this system would:

- Interface with all the equipment that were interfaced with RAMSES system.
- Allow quick interfacing of new type of monitoring equipment, in order to unify the supervision and integrate stand-alone devices, most of them being COTS (Commercial Off-The-Shelf) products.
- Provide a reliable, scalable and cost-effective system.
- Use common CERN software, WinCC OA (WinCC Open Architecture) [2], and JCOP framework (Joint COntrols Project) [3].
- Reduce the delay and the cost of declaring and displaying new devices of known types in the supervision.
- Provide light and fast clients, tailored to the needs of diverse end-users.
- Reduce the overall maintenance and user support effort necessary to maintain the system in operation.

REMUS founded its evaluation of scalability and performance on the study performed by CERN engineering department [4]. The technologies used are commonly employed in large SCADA systems supervising the LHC (Large Hadron Collider) such as the LHC Quench Protection System Supervision or CERN Electrical Network Supervision.

For its development, REMUS applies the same International Standard IEC 61508 [5] that was set up during the development of RAMSES.

CORE FUNCTIONALITIES

Project Objectives

The REMUS project aims at developing a universal software for supervision, control and data acquisition for

12th Int. Workshop on Emerging Technologies and Scientific Facilities Controls PCaPAC2018, Hsinchu, Taiwan JACoW Publishing
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MAINTENANCE AND OPTIMIZATION OF INSERTION DEVICES AT NSLS-II USING MOTION CONTROLS

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Abstract

The purpose of this project is to demonstrate the effective improvements on insertion device performance via upgrades on the motion control software. The insertion devices installed inside the National Synchrotron Light Source II (NSLS-II) storage ring are currently operating at sub/micron resolution with slow speeds, which can limit the scope of user experimentation preferences. We can manipulate the devices with adaptive tuning algorithms to compensate for varying electromagnetic forces throughout motion scans. By correcting positional feedback with encoder compensation and redefining motion programs, we can safely increase the speed to run the same motion trajectories in less time.

INSERTION DEVICES

Introduction

An insertion device (ID) is used at NSLS-II as a photon source for beamlines. These devices include in-vacuum undulators (IVU), elliptically-polarizing undulators (EPU), damping wigglers (DW), and three-pole wigglers (3PW). With the exception of the 3PWwhich has a fixed gap between the three magnetic poles, all insertion devices adjusts the distance between parallel arrays of magnets. This distance is called the ID gap, and EPUs have additional degrees of freedom that can be adjusted horizontally, which controls the polarization of photons produced. This type of adjustment is called the ID phase.

Motion Control System

The motion control system used for the insertion devices comprises of both hardware and software. The hardware used for IDs at NSLS-II are: 64-bit Linux computers; Delta Tau Programmable Multi Axis Controller (PMAC-2) modules [1]; Delta Tau/in-house built power supply modules; Stepper/servo motors (and brakes where needed); Renishaw optical glass linear positional encoders [2]; embedded rotary positional encoders (for some IDs); Ethernet, motor, and encoder cables. The ID software is mainly divided into three parts: configuration on the PMAC, software Input Ouput Controller (IOC), and user interface via Experimental Physics and Industrial Controls System (EPICS) communication [3]. IOC has EPICS applications to channel access interface with motor controllers. The user interfaces for IDs are operator interface (OPI) screens on Control System Studio (CSS) software used facility-wide [4]. These OPIs can set and monitor kinematic parameters of the motion control system. In summary, the major control system components (seen on Fig. 1) are: the drive assembly connected by motors, the motor controller and driver, the IOC, and the OPI.

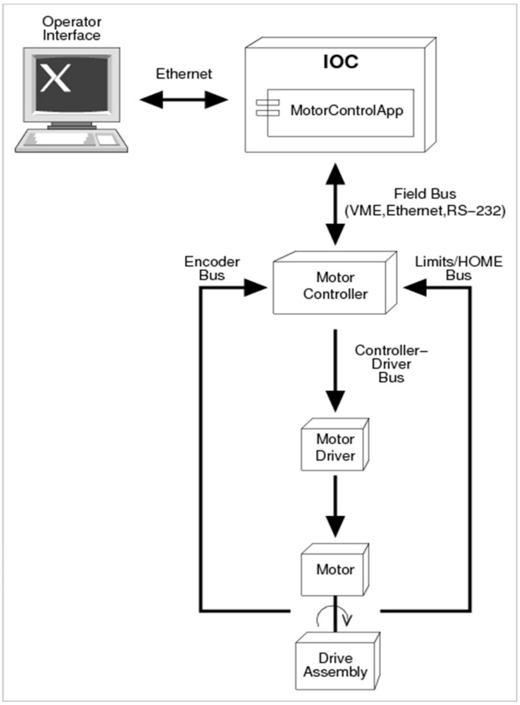

Figure 1: Motion control system components.

3PW/DW Motion Control Setup

The simplest motion control system for an ID at NSLS-II is that of a 3PW since it only involves one motor. A 3-phase stepper motor runs at 2 Amps to rotate the drive assembly. This assembly contains a motor, a gearbox, and a ballscrew, which moves the actual magnetic device horizontally on double supported rails. The direction of this motion in reference to the accelerator beam is inboard (positive direction) and outboard (negative direction). We set the fully outboard position to zero, and the 3PW reaches the fully inboard position when it is aligned with the beam passing through a flattened beampipe chamber section.

For the 3PW, we use a 50-nanometer resolution Renishaw absolute linear encoder for positional feedback. This is directly read on the PMAC on power on, so we always recover the last known position. The software does not require coordinated definitions on the PMAC configuration, so we directly change the position to the axis using jog commands. These move commands are transferred via setpoint and go fields in the OPI seen on Fig. 2 below. We can also enter the desired position using the move in/out command buttons to fully insert/retract the device.