DESIGN AND IMPLEMENTATION OF SESAME'S BOOSTER RING CONTROL SYSTEM

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Abstract

SESAME is a synchrotron light source located in Allan, Jordan. It is currently under construction. It consists of a 22MeV Microtron, an 800MeV Booster Synchrotron, and a 2.5 GeV Storage Ring. The Microtron functions as a pre-injector. SESAME succeeded in commissioning the Microtron in October 2012. The Booster is expected to be commissioned early 2014, the Storage Ring by the end of 2015, and the first beam line in 2016. This paper presents progress made in design and development of the Booster ring's control systems. EPICS is used to build the control systems at SESAME. CSS is used to build the control system's graphical user interfaces. PLCs and one VME are used for custom control of analog and digital signals. A distributed version control system is used to track development of the control systems. Documentation at SESAME consists of a set of design notes, standards, and templates. An isolated machine network is used for communication. Future work includes design and development of PLC and VME alternatives.

OVERVIEW

SESAME's Booster (Fig. 1) is an 800MeV synchrotron that spans 36m in circumference and consists of six cells spread evenly across the ring. Each cell consists of a FODO arrangement followed by a straight section. The Booster is currently under construction. It reuses the main parts of the old BESSY I injector. This paper presents the design and implementation of the Booster's control system, which is divided into seven subsystems: Vacuum, power, RF, diagnostics, timing, cooling, and safety.

Each control subsystem consists of one or more clients, servers, and controllers. Implementation uses the Experimental Physics and Industrial Control System (EPICS) [1]. Clients are implemented using Control System Studio (CSS). Servers are implemented as EPICS Input/Output Controllers (IOC). Custom controllers are implemented using Siemens S7 Programmable Logic Controller (PLC) and VME crates. Fig. 2 shows the topology of the control network used at SESAME.

The client for each subsystem is divided into three parts:

- Tabular form: Shows a summary of the most important parameters for all the devices in the subsystem in tabular form on a single window.

- Graphical form: Shows a summary of the most important parameters for all devices in the subsystem on

a drawing of the Booster ring along with the relative positions of the devices.

- Advanced form: Shows a detailed view of the parameters for each of the devices in the subsystem on a separate window.

Git version Control System (VCS) [2] is used to track development and documentation. All development and administration platforms use Scientific Linux 6.4 [3]. An isolated network, called the machine network, is used for communication between clients, servers, and controllers.

DESIGN AND IMPLEMENTATION

Vacuum

The vacuum subsystem for the Booster consists of seven ion pumps, eight vacuum gauges, three valves, one ion pump controller, two ion pump splitters, two vacuum gauge controllers, and one PLC.

Ion pumps are connected to a single ion pump controller via two ion pump splitters. Vacuum gauges are connected to two vacuum gauge controllers where each controller is in charge of four gauges. Gate valves are connected to the PLC.

A single Moxa server is used to connect all controllers to the EPICS network. RS232 is used to connect the Moxa server to each of the controllers.

A single server running on a Linux-x86 platform is used to control all vacuum subsystem devices. Table 1 shows a summary of the devices used in the vacuum subsystem.

Table 1: Vacuum subsystem devices

Device	Quantity	Manufacturer
Gauge Controller	2	MKS
Pirani Gauge	4	MKS
Cold-Cathode Gauge	4	MKS
Ion Pump Controller	1	Varian
Ion Pump Splitter	2	Varian
Ion pump	7	Varian
Valve	3	VAT
PLC	1	Siemens

Power Supplies

The power supply subsystem for the Booster consists of DC power supplies and pulsed power supplies.

DC power supplies consist of one power supply for the bending magnets, one power supply for the focusing
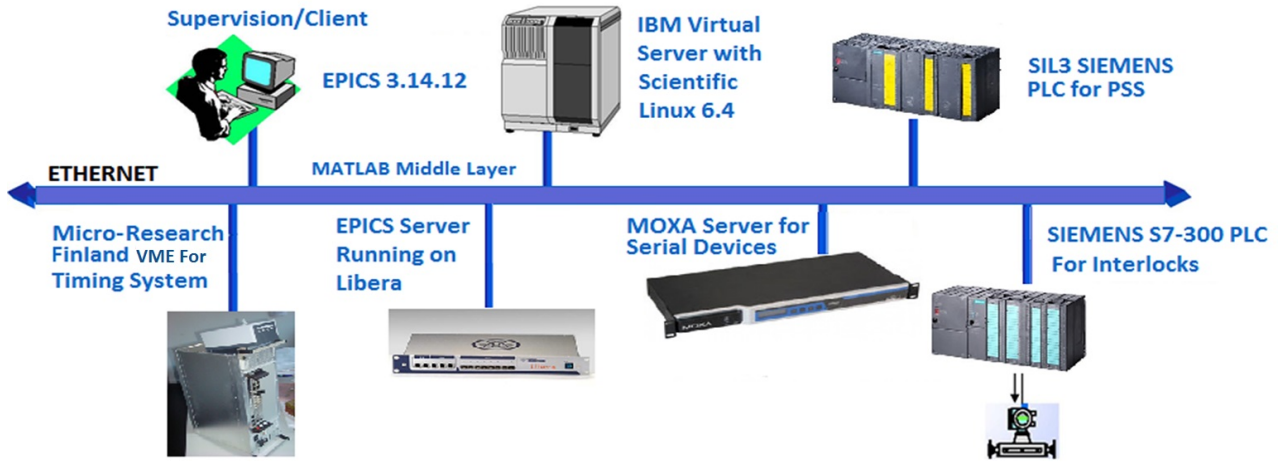
Figure 1: SESAME's Booster Synchrotron

Figure 2: Architecture

quadrupole magnets, one power supply for the de-focusing quadrupole magnets, a synchrobox whose job is to coordinate the trigger and clock for the three power supplies, and six power supplies for six correctors.

Pulsed power supplies are DC power supplies driven by separate pulsed triggering mechanism. They consist of one power supply for the injection septum, one power supply for the extraction septum, one power supply for the injection kicker, one power supply for the extraction kicker, and one power supply for the bumper.

Each of the above mentioned power supplies is connected directly to the EPICS network over TCP/IP.

A single server running on a Linux-x86 platform is used to control all power supplies. The client for one of the DC power supplies is shown in Fig. 3. A summary of the power supplies used is shown in Table 2.

Radio Frequency (RF)

The RF subsystem for the Booster consists of a signal generator, Low Level RF (LLRF) controller, and a transmitter.

The interface on the LLRF controller consists of a number of analog and digital IO's. A PLC is therefore used to
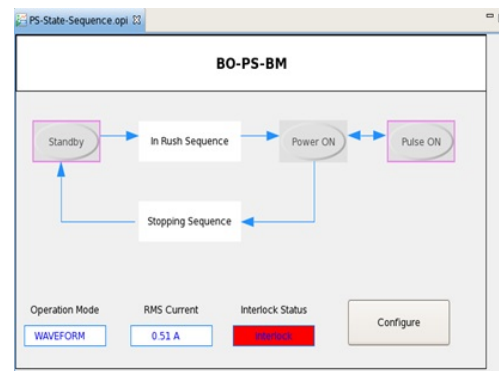

Figure 3: DC power supplies client

control these signals. The transmitter is equipped with an internal web server that enables control and monitoring of its most important parameters.

Each of the above mentioned devices is connected directly to the EPICS network over TCP/IP.

A single server running on a Linux-x86 platform is used to control all devices (except the transmitter). Table 3 shows a summary of the devices used in the RF subsystem.

Table 2: Power supplies

Power Supply	Quantity	Manufacturer
BM	1	Bruker
QF	1	Bruker
QD	1	Bruker
Pulsed	5	Fug
Corrector	6	Bruker
PLC	1	Siemens

Table 3: RF subsystem devices

Device	Quantity	Manufacturer
Signal Generator	1	Work Microwave
LLRF Controller	1	
Transmitter	1	Electrosys
PLC	1	Siemens

Table 4: Diagnostics subsystem devices

Device	Quantity	Manufacturer
Libera	6	Instrumentation Tech
BPM	6	BESSY I
FOM	3	BESSY I
Camera	3	
DCCT	1	Bergoz Instrumentation
FCT	1	Bergos Instrumentation
Shaker	1	In-house
PLC	1	Siemens

Diagnostics

The diagnostics subsystem for the Booster consists of six Beam Position Monitors (BPM), three Foil Monitors (FOM) multiplexed using a video switcher, one externally-triggered digital camera, one Direct Current Current Transformer (DCCT), one Fast Current Transformer (FCT), and one shaker.

Each of the six BPMs is connected to a Libera Electron controller. FOMs (controls and video switching) are controlled using a PLC. The video switcher is used to select one of the FOMs as input to the video card. The externally triggered digital camera is placed at the Booster's injection point to monitor beam injection. The camera's external trigger is driven by the timing system. The DCCT and the FCT are connected to oscilloscopes, which are controlled using their own proprietary software. The shaker consists of a power amplifier along with a set of RF switches that toggle the connections between the BPM and the amplifier. These switches are controlled using a PLC.

Each of the above mentioned devices is connected directly to the EPICS network over TCP/IP.

Each of the six Libera Electron controllers is a hard IOC, hosting its own separate database. The rest of the diagnostic controls are hosted on single server running on a Linux-x86 platform. Table 4 shows a summary of the devices used in the diagnostics subsystem.

Timing

The timing subsystem for the Booster consists of one event generator and one event receiver, both of which are connected to the EPICS network over TCP/IP. The generator and receiver are implemented as two separate cards hosted in the same VME crate. VxWorks is used to run the EPICS server. The crate is manufactured by PSI. The event generator and receiver cards are manufactured by Micro-Research Finland. The client consists of one window for the generator, and another window for the receiver.
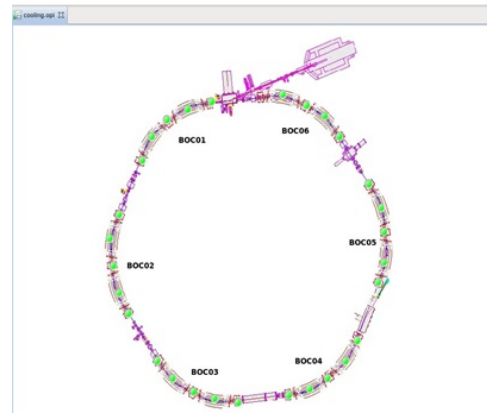
Cooling

Figure 4: Cooling client

The cooling subsystem for the Booster consists of thirty security boxes, one for each magnet. Each security box monitors the coolant's temperature and flow, and triggers an interlock signal in case of a malfunction. A PLC is used to monitor all thirty interlock signals. The PLC is connected directly to the EPICS network over TCP/IP. A single server running on a Linux-x86 platform hosts the EPICS database. They security boxes are designed at Synchrotron SOLEIL. A single client (Fig. 4) shows the status of all interlocks.

VERSION CONTROL

Each subsystem in the Synchrotron requires three developments: One for the controllers, one for the servers, and one for the clients. A version control system is used to track development. Such a system enables collaboration, revisioning, and overall better development workflow.

The structure of the Synchrotron lends it itself nicely to hierarchical design. At the top level is the Synchrotron. The Synchrotron consists of six stages. Each stage consists of one or more subsystems. Each subsystem requires one or more controllers, servers, and clients, regardless of whether these three components reside on the same platform or on separate platforms.
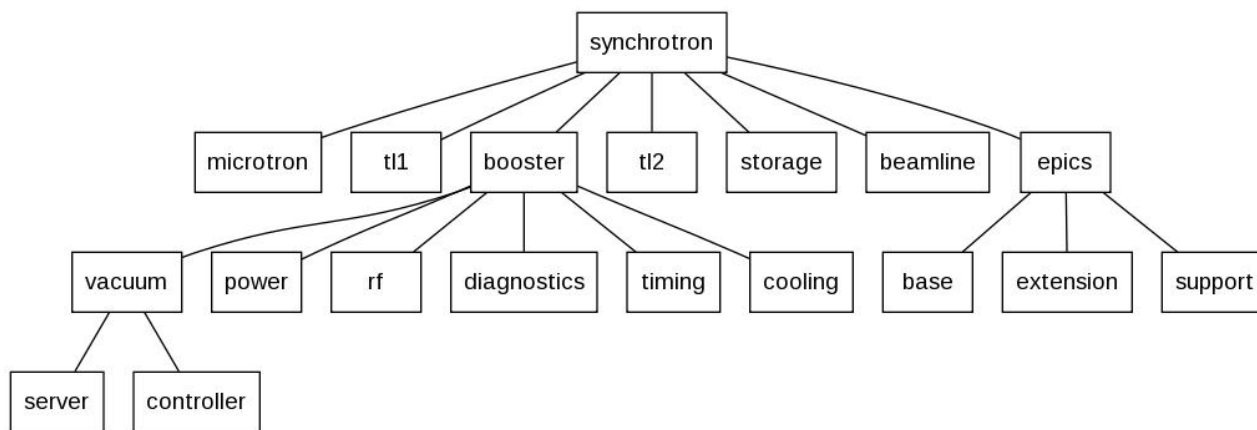
Figure 5: Repository structure

At the bottom of the hierarchy, the controller folder holds documentation (datasheets, user guides, ...etc.) for both the corresponding device and controller. If the controller is built in-house, this folder also contains hardware and firmware design files. The server folder contains the server's software design files. The client folder contains the client's software design files. For practical reasons, clients were moved to a separate repository of their own.

Finally, the epics folder is added at the top level of the hierarchy. This folder hosts EPICS base, extension, and device driver support required for the creation, compilation, and execution of all servers and clients implemented in the repository. An example structure of the repository is shown in Fig. 5.

The version control system uses Git. Git is a light-weight distributed revision and source code management control system. Because it's distributed, Git is ideal for projects that may span multiple teams collaborating over distant geographical locations. Git is open source. Packages are available for Linux, Windows, and Mac operating systems.

DOCUMENTATION

Documentation is divided into the following categories:

- Design notes: The set of design and implementation notes used for software, firmware, and hardware, organized per subsystem and as a single document.

- Standards: Development standards for software, firmware, hardware, networking, graphical user interface, and version control.

- Templates: Used for creating design notes.

A separate repository is used to track all documentation. Wherever possible, Latex is used for preparing documents.

NETWORKING AND COMPUTING

All clients, servers, and controllers are connected to an isolated machine network. 256 IP addresses are reserved for the Booster's control systems. Currently, name resolution is statically maintained. Once the Booster is commissioned, an effort will be made to make name resolution dynamic. Twelve virtual servers are reserved for the Booster's control systems, to run IOC's, repositories, and file transfer servers.

All workstations and servers have been migrated to Scientific Linux 6.4 and EPICS base 3.14.12. Current exceptions to this rule are the Libera devices, which run a Debian variant, and the VME crates, which run VxWorks.

FUTURE WORK

Commissioning of the booster is expected in early 2014. The design and implementation of the Storage Ring and Beamlines' control systems will follow.

SESAME's injection system uses PLCs and VMEs for custom control of analog and digital signals. Other, more cost-effective solutions are currently being studied to serve as substitutes. We are particularly interested in low-cost distributed processing platforms that can be tailored for industrial control applications. The most feasible solution will be selected for design and development. The goal is to be able to deploy hard EPICS IOC's that are both low cost and high in performance.

CONCLUSION

EPICS is used to build the control systems at SESAME. Git version control is used to track development of the control systems. Documentation at SESAME consists of a set of design notes, standards, and templates. An isolated machine network is used for communication. Future work includes design and implementation of the control systems for the Storage Ring and Beamlines.

REFERENCES

[1] http://www.aps.anl.gov/epics/

[2] http://git-scm.com/

[3] https://www.scientificlinux.org/