EXTENDING VEPP-5 CONTROL SYSTEM BY MIDDLEWARE FOR INJECTION/EXTRACTION AUTOMATION

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Abstract

CX and EPICS are used at VEPP-5 Injection complex. Each system is in charge of some part of accelerator devices. Middleware layer was added in order to make data processing and facility-level control actions more straightforward. Middleware is separated from clients layer by means of additional CX-server. Architectural approach is considered on the example of injection/extraction automation.

INTRODUCTION

In order to provide electrons and positrons for colliders VEPP-5 injection complex [1] in the Budker Institute of Nuclear Physics is being built. This complex includes linear accelerator-based electron-positron source (preinjector) and damping ring. There are two existing injection complex beam users VEPP-4 and VEPP-2000. Charm-Tau Factory project claims the complex to provide positrons [2].

VEPP-4 and VEPP-2000 colliders will require both electron and positron beams with relatively low injection rate. In order to supply users injection complex will switch between users (further switch user) and switch between electrons and positrons (further switch particles type). It is required to store electrons and positrons in damping ring and transfer beam to users on complicated schedule. All mentioned above control actions compose injection complex main loop (machine loop) which is easier to implement by software in this case. Basic-level control was implemented by CX and EPICS software control systems. In order to create facility-level control for injection complex it is required to use both systems. Injection complex synchronization system is in charge of machine loop implementation. Synchronization system hardware was changed in order to support selected operation model.Software and hardware design based on the following principles is discussed:

- existing software and hardware infrastructure is used,
- software is suitable for regular machine operation,
- few copies of any GUI application started on the same or different computers are allowed,
- developers work is minimized.

DESIGN

Requirements

Requirements for injection/extraction automation arise from complex tasks to serve colliders. Let's consider colliders injection loops. VEPP-4 injection cycle consists of the following stages: storage to VEPP-3 up to 4^{11} particles, 2^{10} particles/injection, time between injections at least 1 second; acceleration to experiment energy, transfer to VEPP-4 and change VEPP-3 polarity, process duration about 7 minutes; then those stated above are repeated for other particles. Beam for VEPP-2000 is to be injected to BEP. 1.1^{11} 1.4^{11} particles are required to be injected at once. BEP uses 30 s to accelerate, transfer particles and change polarity. VEPP-2000 is expected to require 8 injections of each type of particles as initial collider filling. Refill is to be done in 30-50 s with usual amount of electrons and positrons.

According to beam users working schedule it is required to change machine settings from electrons to positrons or from one user to another one every 30 seconds. Highly automated control has to be implemented to meet this tight machine schedule. Currently injection complex operates with engineering software which presents full set of measurement and control points. Regular machine operation requires dramatic reduction of information amount presented to operator.

In order to avoid additional radiation load on equipment no beam should be accelerated without reason. Continuous start mode with masking was previously used for preinjector. Equipment in this mode can emit undesirable start signals since mask command execution time can be larger than time to next start. Preprogrammed number of starts mode ("counter mode") has to be implemented for preinjector beam systems. Continuous starts mode is being used for high power RF systems since it keeps constant thermal state of accelerating structures.

Start signals for extraction are provided by RF matching system in order to transfer beam to user. Currently this system is under development. Internal start possibility being presented for extraction and transfer channels is required for testing and tuning. RF matching system will continuously generate starting signals. Therefore synchronization hardware has to pass single start on request ("single-pass mode"). Internal starting signals can be provided by any continuous-mode channel of start generator.

Let's summarize requirements for the machine control system changes:

- "counter mode" must be implemented for preinjector beam systems,
- "single pass mode" must be implemented for extraction signals,
- automatic control software must organize user requests processing, beam storage and transfer with all

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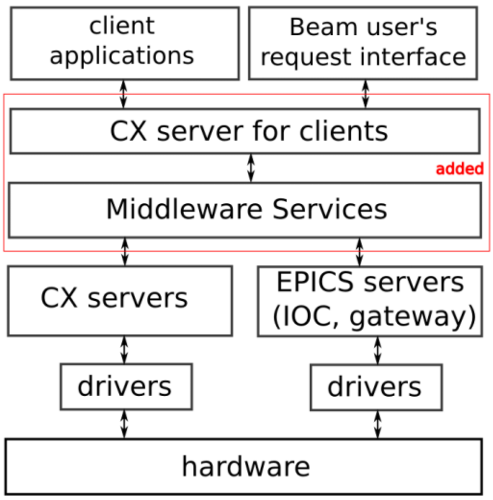

Figure 1: Injection complex software structure with middleware.

required operation mode changes,

- few copies of operator applications can be launched.

General solutions

In order to meet the requirements operator applications have to be isolated from closed-loop control code. Since CX and EPICS are used in control system we have to create common server side processing infrastructure. A logical middleware layer and additional CX-server is proposed to be added (see Fig. 1). Middleware layer consists of client-space services which implement facility-level control, closed-loop control and data processing. Top-level CX-server is in charge of communication with clients. Currently services can be implemented with C/C++ when throughput is crucial or with python for fast development. GUI applications are communicating with control system via CX only and don't implement any closed-loop control. This allows few copies of application to be started and makes GUI programs development more straightforward.

INJECTION/EXTRACTION AUTOMATION

Device level control for injection complex was implemented earlier including hardware, drivers, servers and engineering GUI applications. Specified above requirements lead us to implement some hardware and software changes. Let's brief discuss equipment and programs involved to injection and extraction control with emphasis on made changes.

Hardware

One turn injection with pre-kick of a stored beam is used in a damping ring. Injection system consist of four kickers (see Fig. 2) and their high voltage generators [5]. Currently injection system can reliably operate with up to 12.5 Hz repetition rate. Generators controlled by synchronization

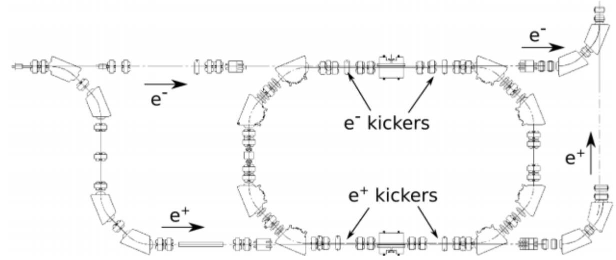

Figure 2: Damping ring kickers placement layout.

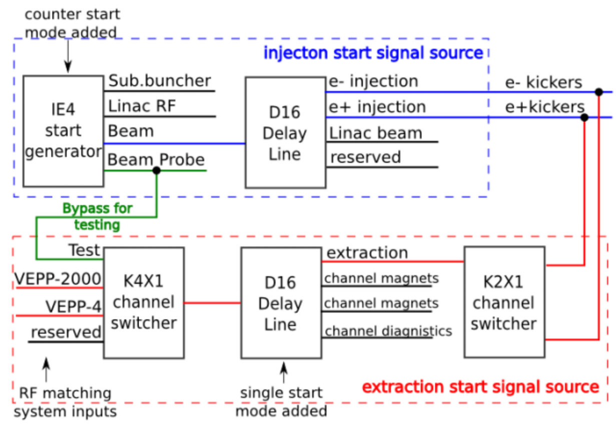

Figure 3: Kikers start signals sources layout.

system (providing start signals), CAC208 DAC/ADC (generator voltage settings) and fast ADC (generator waveform acquisition). Channel switchers are used to select which pair of kickers is operated.

Part of synchronization system shown on Figure 3 is in charge of carrying out injection and extraction actions. Other automation hardware defines operation mode. Synchronization system is hosted in CAMAC and controlled with EPICS. Start generator IE4 signals are used to inject the beam to damping ring. Extraction involves signals from shared with beam users RF matching system. Test extraction can be done with bypass from beam probe channel which continuously generate starts at 1 Hz repetition rate. This generator has 4 channels to support operation of all complex pulsed devices: 50 Hz channel for subharmonic buncher, 1 Hz channel for slow devices, 50Hz/N channel for RF system and, 50HZ/N/M for beam and injection systems. RF system and beam systems channels were separated to keep accelerator thermal mode while beam acceleration is not required. In order to meet mentioned above requirements "counter mode" was added to IE4 start generator beam channel and single pass mode was added to first D16 delay line in extraction circuit.

Damping ring beam current is measured with direct current current transformer (DCCT). Closed-loop injection control based on DCCT data is to be implemented. DCCT current is measured with CAC208 and provided via CX-server.

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Software

Injection and extraction automation is a machine main loop implementation. The problem consists of following tasks: machine operation mode changes, procedures (inject, extract,...), create facility-level data, process user requests and schedule tasks, bring data to top-level CX-server. Middleware services were created for each task (see Fig. 2). There are following basic kinds of services: gateway, data processor, aggregator, action and control loop. Let's describe their features.

- Gateway with simple data processing capabilities was implemented in general way and is suitable for many cases.
- Data processors are individually designed. DCCT data processor and magnetic system failure trackers are implemented to date. It is planned to create failure and readiness trackers for all control devices.
- In order to simplify facility-level actions and control loops they should operate with facility-level data. Aggregators are used to provide facility-level data. And, or and sum aggregators are implemented to date.
- Actions and control loops are individually designed but have few common features. In order to generalize run control and interrupts processing actions and control loops must support at least start, stop, continue and reset state commands which are sent via clients CX.

Common services design points:

- Corresponding hardware-side data can conflict with client-side data. When service is starting hardware considered as reliable data source. In a runtime service solve data conflict on it own.
- Service settings that can be changed run-time are transferred by CX server. SDDS [4] files are used for other settings.
- CX and EPICS both have client libraries for C and Python. If it's possible Python should be used to implement service in object-oriented way.

Currently Python wrappers for QT, CX and EPICS CA were used for implementation of all services. This way was tested to be good for all non-vector channels. Vector channels processing will require C/C++ implementation.

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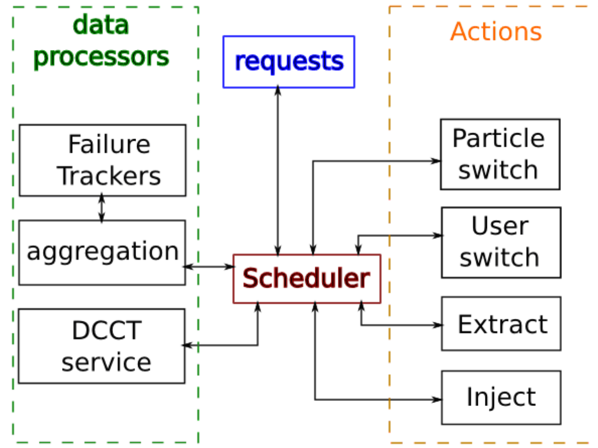

Figure 4: Injection/extraction control services.

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