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The VEPP-2000 Collider Control System: Operational Experience

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Abstract
The VEPP-2000 collider was commissioned and operated successfully in 2010-2013. During the operation the facility underwent continuous updates and experience in maintenance was acquired. Strong cooperation between the staff of the accelerator complex and the developers of the control system proved effective for implementing the necessary changes in a short time.

Keywords
Control system; accelerator; collider.

1 Introduction

VEPP-2000 is a collider with a luminosity up to $1\text{x}10^{32}\text{cm}^{-2}\text{s}^{-1}$ and a beam energy up to 1 GeV per beam [1-2]. This project is an extension of the previous VEPP-2M facility. Construction of VEPP-2000 started in 2001. In 2007 first luminosity was produced. Since the end of 2009, the collider has delivered beams to the experiments. In 2013 a long shutdown started, which was dedicated to the upgrade of a wide range of subsystems. During operation VEPP-2000 used the injection chain of its predecessor VEPP-2M (see grey area in Fig. 1). This was later replaced with a link-up to the new injection complex VEPP-5 [2]. It consists of the old beam production system and Booster of Electrons and Positrons (BEP) with an energy limit of 800 MeV. The collider is equipped with two particle detectors [3], the Spherical Neutral Detector (SND) and the Cryogenic Magnetic Detector (CMD-3), which are located at dispersion-free low-beta straight sections. The final focusing is realized using superconducting 13 T solenoids.

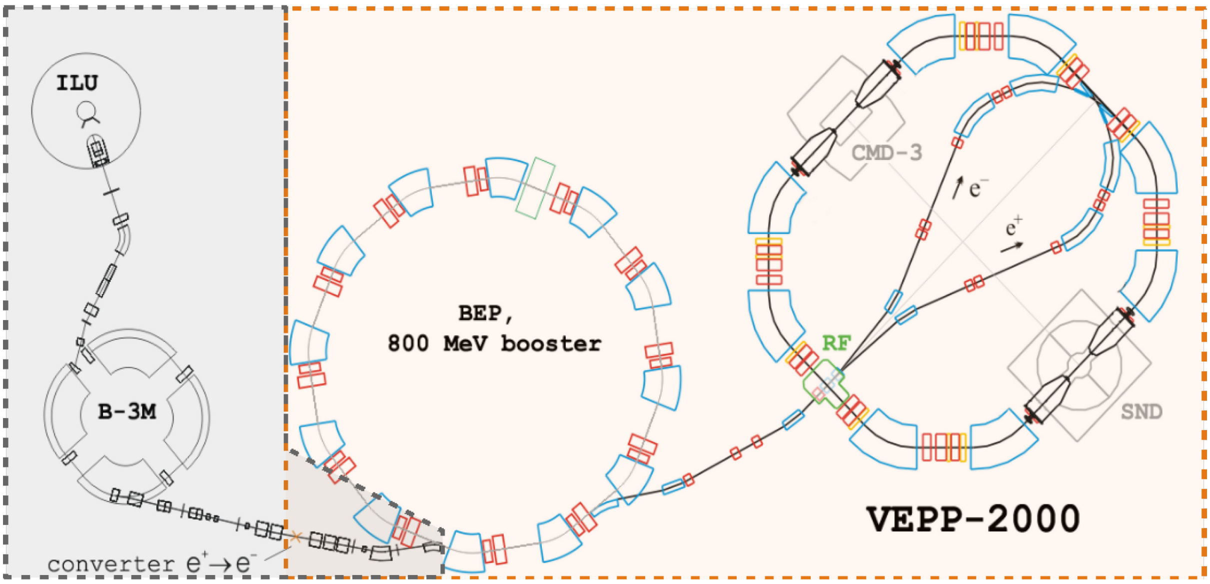

Fig. 1: The layout of the VEPP-2000 facility

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2 Control system

The control system of the VEPP-2000 accelerator facility consists of the following tightly coupled parts (see Fig. 2):

- Hardware – analog-to-digital converters, digital-to-time converters, etc.,
- Software – system software (operating system, databases), application software (hardware servers, user level),
- Infrastructure – computers, networks.

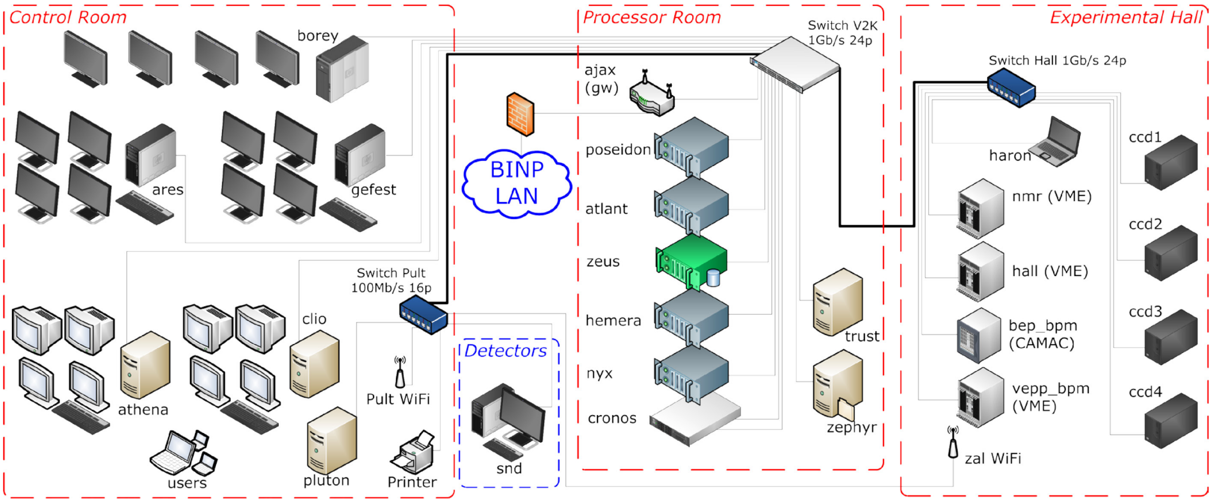

Fig. 2: The network layout of the VEPP-2000 acceleration complex

From the automation point of view, the accelerator complex VEPP-2000 is a complicated system. Over 2000 control channels and 3000 monitoring channels and their joint usage impose rigid restrictions to the control system. These channels are divided into two groups: scalars (like beam current or beam energy with a typical update rate of 1-2 Hz) and vectors (like CCD, BPM, pulsed element measurements).

2.1 Hardware

The VEPP-2M control system was based on the CAMAC standard and in-house BINP devices. Most of the CAMAC devices were designed and manufactured 20 years ago. It was decided to replace obsolete devices with modern ones. CAN-bus was chosen as the base technology [4]. CAMAC devices were left for systems with high data rates (like fast-ADCs) and legacy system which were due to be removed soon. A few VME devices were used for beam parameter measurements. All devices are BINP manufactured. Migration to CAN-bus based devices allows to install devices near the control units and to reduce the number of cabling connections.

Significant efforts were made to design hardware parts as a set of loosely coupled subsystems. Such an approach facilitates changes or upgrades of individual subsystems without affecting other subsystems. For example, CAMAC devices for the measurement of pulsed magnets were replaced by CAN-bus devices without affecting the whole control system.

2.2 Software

1.1.1 System software

Linux-based systems proved to be reliable. Therefore Gentoo Linux was chosen for the operating system. A source-based distribution was chosen, allowing for accurate configuration and tuning. During experimental runs in 2010-2013 it appeared that system-wide updates or even software installation could only be done during shutdown periods. This resulted in high maintenance costs. Therefore it was decided to migrate to a binary distribution with long-term support, and a stable Debian release was chosen.

1.1.2 Application software

The application software development started at the same time as the assembly of the facility. A first version used for magnetic measurements had a two-layer client-server architecture. Through continuous updating the architecture was changed to a traditional tree-layer structure (see Fig. 3).

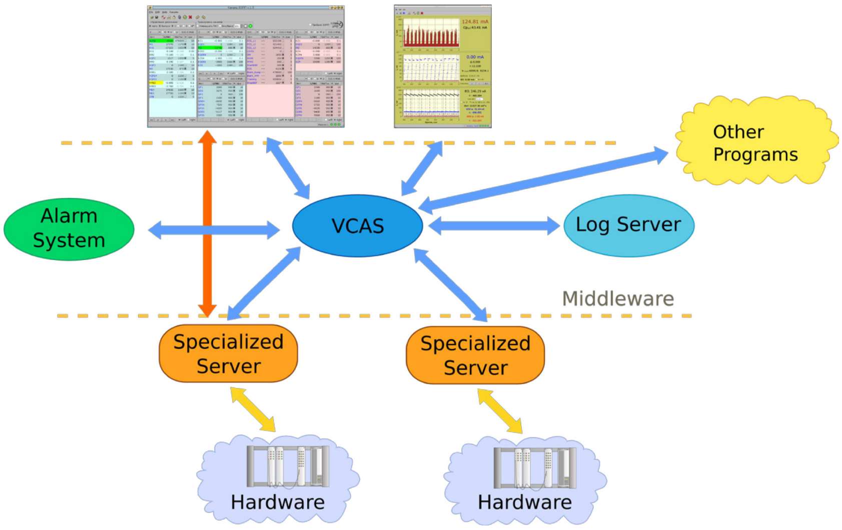

Fig. 3: The VEPP-2000 Software scheme

Special servers control CAN or CAMAC buses and provide access to hardware for client applications.

The middleware layer consists of applications that control particular subsystems and provide derived data for other applications. The main application of this layer is VCAS (VEPP-2000 Channel Access Server). It is similar to modern Message Queue Software (like AMPQ, RabbitMQ, ZeroMQ). It was developed to configure subsystems and applications via system-wide events or commands (injection, regime changing).

The third layer comprises GUI applications, which provide the operators of the accelerator complex with the controls for beam tuning and diagnostics. The developers interact frequently with the operators in order achieve a convenient implementation.

Strict time constraints and the lack of appropriate open-source solutions resulted in the development of a text-based communication protocol. It satisfies most of the requirements (transferring small control commands and measurements with rates up to 1 Hz). However it was not designed for high data rates (CCD, BPM). This led to the creation of several incompatible protocols during operation.

Software that controls critical subsystem or should provide high responsiveness is implemented in C/C++. Python and Java are used for utilities and non-critical applications. The GUI is implemented with Qt library.

2.3 Infrastructure

The security and reliability of the network of experimental facility is an important issue. At the early stages of development of the control system it was decided to create a private network to reduce security risks thereby preventing exposure of the control software to the Intranet. To provide access to external resources a gateway is used. This approach allows to protect the control system against Intranet failures.

Another important decision was to provide wireless connection across the facility (control room, experimental hall, control equipment room). It allows to reduce the number of cabling connections and local control panels.

3 Future applications

During the operation the VEPP-2000 team acquired significant experience in control system development and maintenance. Common use-cases were collected. This experience can be applied to other facilities. For example, new software developed for the VEPP-5 injection complex (which will be used as injector of positrons for the Super Charm-Tau factory) is based on concepts of the VEPP-2000 control software.

The experience can be also applied to the design of the control system of the Super Charm-Tau factory. Building a control system fully from scratch for such a facility would be very expensive. On the other hand, the use of out-dated or unsupported software or hardware would result in high maintenance costs. Furthermore there is the issue of technology changes and trends. More than ten years have passed since the start of the VEPP-2000 construction. During this time many new technologies and control system software applications have appeared or were significantly improved (TANGO, EPICS, BINP in-house). These are worth to be evaluated, for example in isolated subsystems or test stands. In this context work has started on developing a TANGO-based control system for a test stand at the BEP ring.

4 Conclusion

Construction of the VEPP-2000 control system started more than 10 years ago. During this period, it underwent significant changes. Experience acquired during the operation and continuous updates could be applied to other facilities, such as the Super Charm-Tau factory, a future mega-science project at BINP.

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