MODERNIZATION OF VEPP-2000 CONTROL SYSTEM*

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Abstract

Electron-positron collider VEPP-2000 delivered data for the high energy physics since the end of 2009. In the summer of 2013 the long shutdown was started dedicated to the deep upgrade of the wide range of subsystems. The main goal of the improvements is to reach or exceed design luminosity in the whole energy range from 200 MeV to 1000 MeV per bunch.

The hardware of the accelerator complex consists of high current main field power supplies, low current power supplies for steering and multipole magnets, pulsed power supplies for channel's elements, RF subsystems, BPM and some other special subsystems (such as vacuum, temperature, etc.). The control system is based on CANbas, CAMAC and VME devices. The wide range of software corresponding to specific hardware subsystems forms complicated interacting system that manages all parts of the VEPP-2000 accelerator facility. Automation software is running on several TCP/IP connected PC platforms under operating system Linux and uses client-server techniques.

The paper presents general overview and changes made in architecture, implementation and functionality of hardware and software of the VEPP-2000 collider control system.

VEPP-2000 PROJECT

VEPP-2000 electron positron collider [1] was commissioned and spent three successful runs 2010-2013 collecting data at whole energy range of 160÷1000 MeV per beam [2].

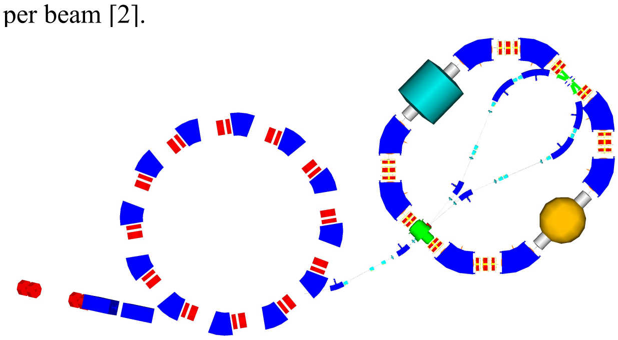

Figure 1: VEPP-2000 facility layout.

During this work VEPP-2000 used the injection chain of its predecessor VEPP-2M which has worked at BINP over 25 years in energy range up to 1.4 GeV in c.m.s. and has collected of about 75 pb^{-1} integrated luminosity. That machine worked at lower energy (< 700 MeV) and showed luminosity 30 time lower than designed value of 10^{32} $cm^{-2}s^{-1}$ for VEPP-2000 at 1 GeV. As a result the positron production rate was not enough to achieve beams intensity limited only by beam-beam threshold. This restriction will be cured by link up via 250 m beamline K-500 [3] to the new injection complex VEPP-5 capable to produce intensive electron and positron high quality beams at energy of 450 MeV. The layout of the VEPP-2000 complex is presented in Fig. 1. The complex consists of Booster of Electrons and Positrons (BEP) and the collider itself with two particle detectors, Spherical Neutral Detector [4] and Cryogenic Magnetic Detector [5], placed into dispersion-free low-beta straights. The main design collider parameters are listed in Table 1.

Table 1: VEPP-2000 Main Parameters (at E = 1 GeV)

Parameter	**Value**
Circumference (C)	24.3883 m
Energy range (E)	200 ÷ 1000 MeV
Number of bunches	1 × 1
Number of particles per bunch (N)	1×10^{11}
Betatron functions at IP ($\beta^*_{x,y}$)	8.5 cm
Betatron tunes ($\nu_{x,y}$)	4.1, 2.1
Beam emittance ($\varepsilon_{x,y}$)	1.4×10^{-7} m rad
Beam–beam parameters ($\xi_{x,y}$)	0.1
Luminosity (L)	1×10^{32} cm^{-2} s^{-1}

CONTROL SYSTEM OVERVIEW

The architecture of VEPP-2000 software [6] is based on three-layer structure (see Fig. 2). Specialized services (hardware layer) control one or several CAN or CAMAC buses and allow client applications to have access to hardware. The main application of Middleware layer is VCAS (VEPP-2000 Channel Access Server). Third level is presented with GUI applications, which provides to facility operator powerful and convenient instrumentation for beam tuning and diagnostics of possible systems malfunctioning. For the high loaded data channels like control systems of magnetic structure of storage and collider rings it is possible direct communication between GUI and hardware layers. Another important application in the middleware layer in specially designed Log Server.

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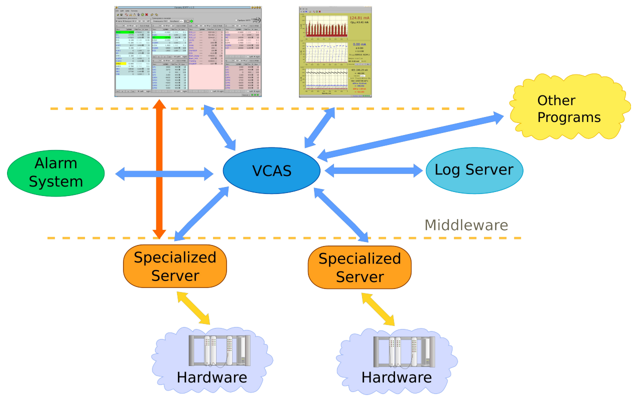

Figure 2: VEPP-2000 Software scheme.

Alarm System

VEPP-2000 collider is a complicated system it's state is characterized by sousands of parameters. Sometime it is difficult to find out system diviation in time. To solve this problem Alarm System was developed. Alarm system is rule based. Every rool could depend on many channels. Alarm system is written in javascript and based on asynchronyos IO library Node.js. Web user interface are embedded in system and provides on-line rule editor. Such approach provides flexible way for rule definition and allows to reduce number of elements to maintain.

Logging Server

The Logging system [7] is aimed at and saving and tracking of parameters changes. It is build on client-server architecture. Logging server is core element. System was deployed in 2011. After one year and a half of successfull operation new version of logging server was developed. Main goal was to improve maintainability. To achieve this goal custom made subsystem and modules were reimplemented with standart or widely used libraies and frameworks. For example network custom made submodule was replaced with Netty based. To provide more simple way for extending logging server with new storage backends and data types server's structure also was revised (see Fig. 3).

At present time the following backends are implemented:

- ***In memory*** – all data stored in memory.
- ***RDB*** – storage relation database as backend
- ***BDB*** – BerkeleyDB JE
- ***Sync*** – synchronize data from source to destination

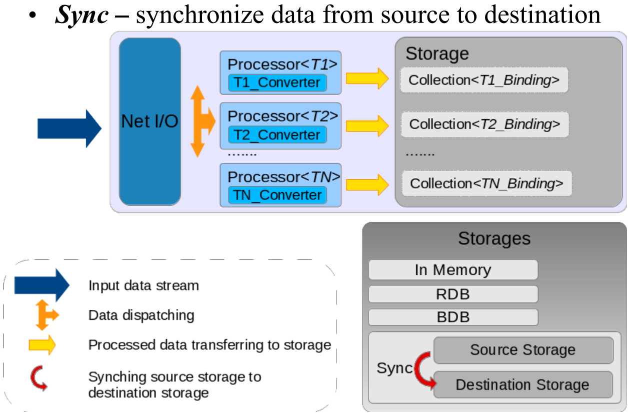

Figure 3: Logging Server structure.

Supervision subsystem

Distributed nature of control system make it necessary to control started services and to monitor resource consumption. To accomplish this task dedicated service was constructed. It base on Supervisord process manager. Custom plugins were developed for resource consumption monitoring per process and entire machine mode. To aggregate information from different machines, Qt based end user apllication was developed.

Beam Position Monitor

Before 2012 2013 working season the Beam Position Monitor System (electrostatic BPM) was equipped with new electronics designed and produced at BINP. New design allows combining the preamplifier and ADC in a single device located nearby from pickup electrodes. Pickup station (shown at Fig. 4) has 4 inputs for analogous signals from pickup electrodes and 3 inputs for from VEPP-2000 timing system (RF frequency, revolution frequency, external trigger). Each input signal from pickup passes through 420 MHz lowpass filter, low noise tunable attenuator (dynamic range 20 dB) and digitized with 14 bit ADC. Wide bandwidth of electronics allows the separate measurements of electron and positron bunches with time interval between bunches up to 20 ns.

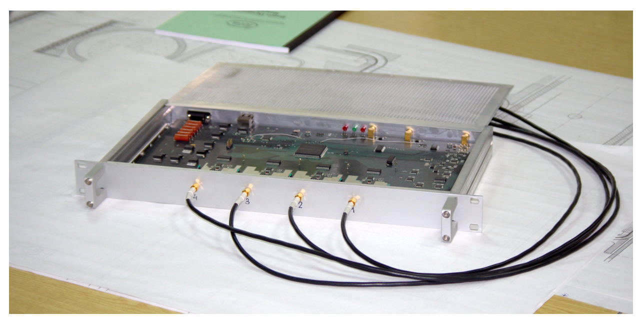
Figure 4: Pickup station.

New system is capable to store up to 8192 points per channel with turn by turn resolution (at revolution frequency) in memory for future use so called fast acquisition, and up to 1024 points with averaging slow acquisition.

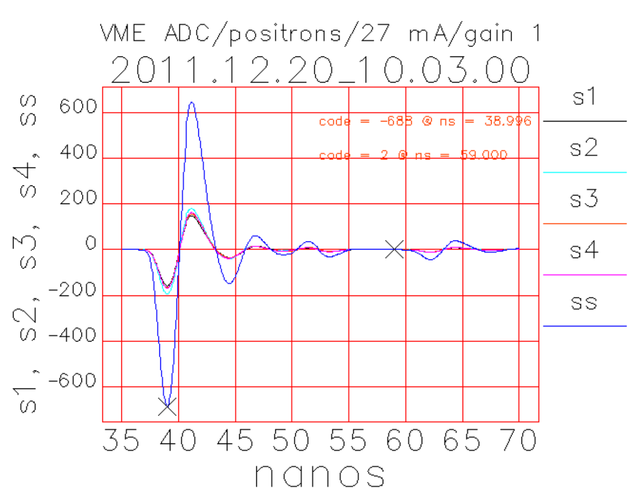

Figure 5: Signal from pickup electrodes.

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The VME interface allows to have 8192 turns of the beam history at 5 Hz frequency and beam position (2048 averaging) at 10 Hz. This bandwidth is fully limited by VME bus and should be improved in new Ethernet interface (prototype will be commissioned until end of 2014). Our estimates show bandwidth limited only by Ethernet capabilities. Fig.5 shows digital output of pickup station while single bunch flew through BPM (picture taken with stroboscope method by varying digital delay between ADC clocks and revolution frequency).

Specroscope

For BPM's data visualization special software “Spectroscope” was developed. Spectroscope provide visualization for beam turn-by-turn position, oscillation spectrum and spectrogram. Frequency diagram is also provided. Spectroscope is written in Python with extensive usage of Pyqtgraph, PyQt and NumPy libraries (Fig. 6).

Figure 6: Spectroscope user interface.

NMR

In 2013 the system of energy determination with use of NMR gauges was upgraded with new processing modules. These modules are made in 19 inch 1U form factor and include all the needed electronics onboard. The new system allows to provide measurements of all NMR channels simultaneously. The processing power of the module's CPU is enough to make all the calculations in time comparable to the measurement time. It made possible to reduce the program architecture of the system to just two levels – client and server. The whole time of the energy determination now is just 5 seconds in contrast to 40 seconds with previous system. This value is satisfactory for VEPP2000 as it is more than 10 times less than the typical ramping time.

CONCLUSION

During the 2010-2013, VEPP-2000 control system have been proved as reliable and consitent. Nevertheless, system development and enhancment are still under way. Significant efforts were made to increase accuracy, to reduce time lags, to provide more useful information and as a result to improve user experience.

Some efforts all ready resulted in new electronics and software for NMR and BPM subsystem, what significantly reduce required time for facility tunning. Some of them, like Alarm System and Supervisor Subsystem will reduce complexity of facility control.

The control system of VEPP-2000 is flexible system and allows very fast development of a new, more powerful application.

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