AUTOMATION OF OPERATIONS ON THE VEPP-4 CONTROL SYSTEM

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ABSTRACT

The upgraded VEPP-4M electron-positron collider [1, 2] is under operation since 1990. The energy range of the collider is from 1.5 up to 5.5 GeV. The injector to the collider is 2 GeV VEPP-3 storage ring VEPP-3. A lot of experiments on high energy physics, nuclear physics, and experiments with using of synchrotron radiation were performed on the VEPP-4 facility.

Support of the corresponding operations on the accelerators is one of the main tasks of the control system. The solution of this task requires interaction of many programs in different computers, integration of special electronics and synchronization devices. A wide frame of experiments requires a lot of operation modes on accelerators and many sequences of operations.

This paper describes details of operations automation on the VEPP-4 facility.

DESCRIPTION OF VEPP-4 FACILITY

General Layout

The VEPP-4 accelerator facility consists of the VEPP-4M collider with 365 m circumference, VEPP-3 storage ring with 70 m circumference, 350 MeV pulse electron/positron injector, 50 MeV LINAC for production of positrons. There are two pulse transfer lines between the rings. The layout of the VEPP-4 facility is shown in Fig.1.

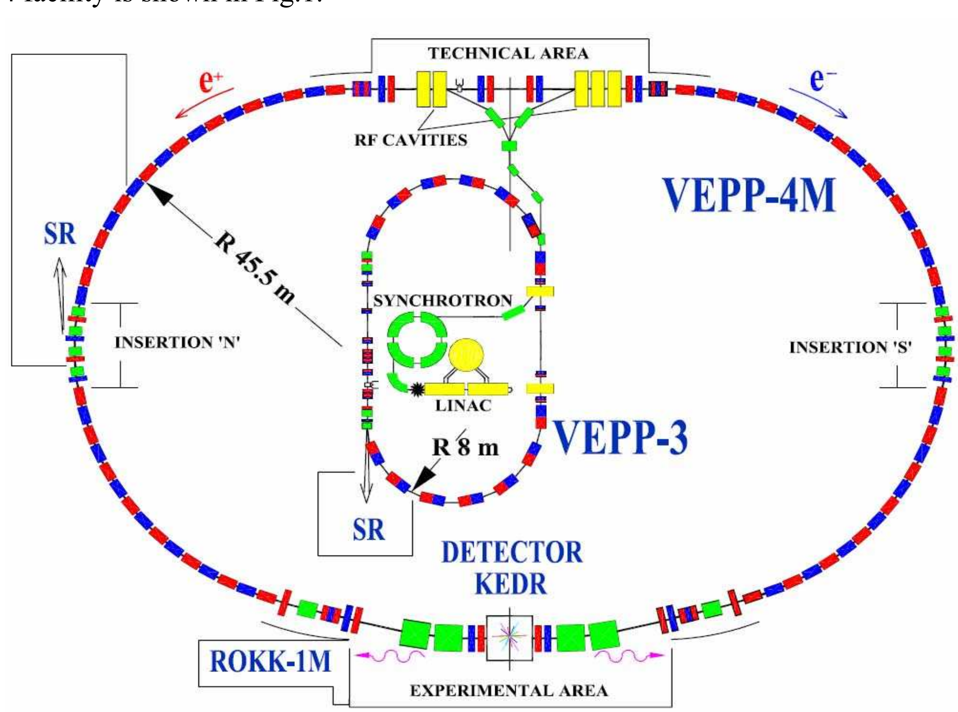

Figure 1: Layout of the VEPP-4 facility.

The pulse injector provides electron or positron beam ones per second with number of particles about 10^{10} electrons or 2.5×10^{8} positrons in a single bunch. It allows us to store the beam current up to 200 mA of electrons or 60-70 mA of positrons in a single bunch in the VEPP-3 storage ring at the energy of 350 MeV. The time of accumulation of positrons is about 20 minutes. The changing of polarity of particles takes about 5 minutes. The accumulated beam can be accelerated in VEPP-3 up to the energy of 2 GeV during 4 minutes.

We have two modes of operations on the VEPP3-3 storage ring: one mode provides experiments with beams on VEPP-3 in the energy range 1.2 - 2 GeV, in another mode VEPP-3 is used as the injector to the VEPP-4M collider on the energy of 1.5 – 1.85 GeV.

List of experiments

Both rings, VEPP-3 and VEPP-4M, are used for providing experiments. In spite of the fact that VEPP-3 is the booster for VEPP-4M, there is a possibility to perform different experiments on VEPP-3 and VEPP-4 simultaneously.

There are two groups of experiments on the VEPP-3 storage ring:

- Experiments based on using of sinchrotron radiation [3].
- Experiments for studying of the electromagnetic form factor of the proton on the deuteron target [4].

These experiments require the beams in the VEPP-3 ring with intensity up to 200 mA and energy from 1.2 GeV up to 2 GeV. The life time of the beam is about 5 hrs at 2 GeV and 100 mA.

VEPP-4M provides next experiments:

- Experiments on high energy physics on the detector KEDR placed in the middle of experimental area [5] (see Fig.1). Last years experiments were being run at the energy range from 1.5 GeV up to 1.9 GeV at the region of Ψ-meson and τ-lepton. In this case VEPP-4 provides 2x2 electron/positron bunches in the VEPP-4M ring with total current about 15 mA at the energy 1.8 GeV. The peak luminosity in this case is about 2×10^{30} $cm^{-2}s^{-1}$.
- Experiments on nuclear physics using the beam of back scattered compton quanta on the ROKK-1M experimental facility (see Fig.1). For this kind of experiments VEPP-4M provides up to 8 bunches of electrons at the energy range up to 5 GeV.
- Experiments with synchrotron radiation on the VEPP-4 beam lines. This experiments are in the stage of construction. There is only one operable beam line in the VEPP-4M synchrotron radiation hall at present time.

THE VEPP-4 CONTROL SYSTEM STRUCTURE

The VEPP-4 control system includes 12 control computers which are CAMAC based home developed microcontrollers Odrenok [5]. The layout of the VEPP-4 control system is shown in Fig.2.

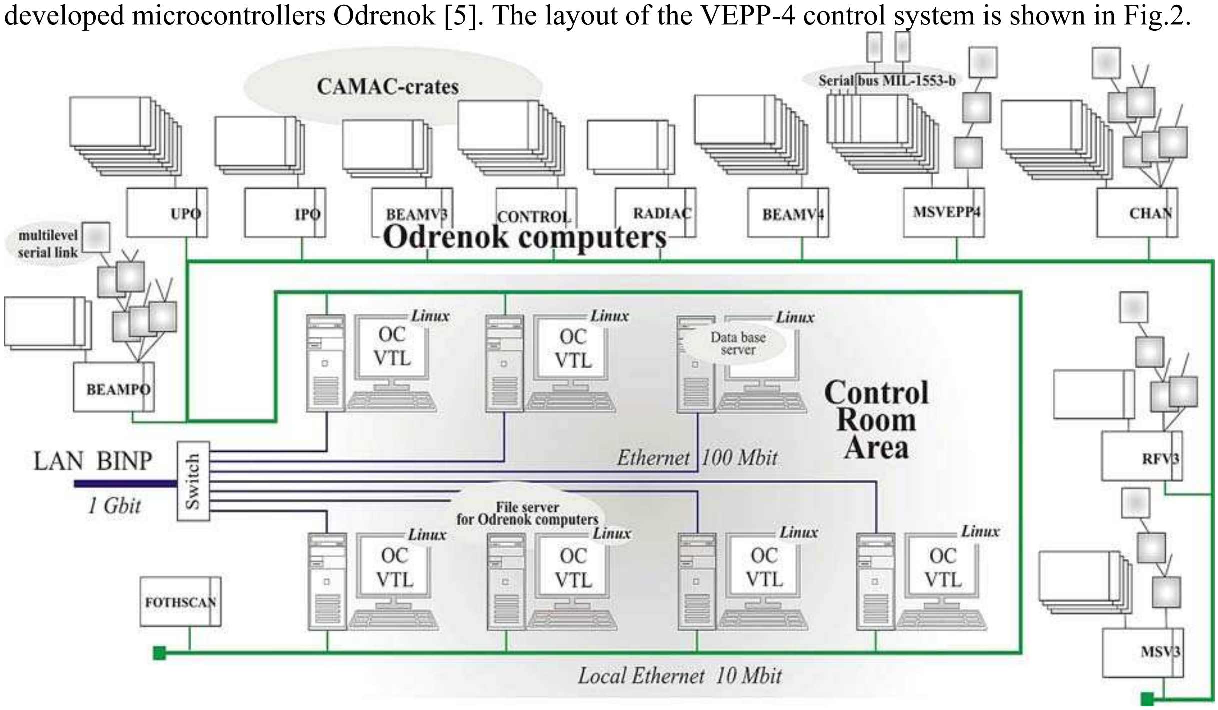

Figure 2: The layout of the VEPP-4 control system.

So, most of the control and measuring electronics are based on CAMAC. The total amount of CAMAC modules is about 600. All the modules are distributed between 65 CAMAC crates. Some part of electronics us not CAMAC and use home developed serial interfaces [1].

Also several PC's are included to the control system as control room consoles, graphical and archive machines.

The distribution of the electronics and the control and measurement channels is shown in the Table 1.

Table 1: Electronics and control/measurement channels of VEPP-4 control system.

	Name of computer	Functions	CAMAC crates	Modules	Control channels	Measure ment
1	MSV4	Control of VEPP-4M collider	9	77	330	583
2	BEAMV4	Beam diagnostics on VEPP-4M	9	96	–	280
3	MSV3	Control of the VEPP-3 magnetic system	5	42	125	80
4	RFV3	Control of the VEPP-3 RF system	2	22	30	15
5	BEAMV3	Beam diagnostics on VEPP-3	4	41	–	100
6	UPO	Control of the injector	9	83	135	30
7	IPO	Control of the injector	4	47	1	100
8	CHAN	Control of the transfer line between VEPP-3 and VEPP-4M	8	75	135	110
9	BEAMPO	Beam diagnostics on the pulse transfer lines	3	20	24	348
10	CONTROL	Temperature and vacuum measurments	8	39	–	710
11	FOTHSCAN	The VEPP-3 orbit stabilisation	1		–	1
12	RADIAC	Radiation monitoring]	3	26	–	36
		Total	65	568	632	2393

One Odrenok (MSV4) provides the control of the power supplies and RF system of VEPP-4M collider. There are more than three hundred DC power supplies, RF system on VEPP-4M. Next one (BEAMV4) provides beam diagnostics.

Four Odrenoks (MSV3, RFV3, BEAMV4, FOTHSCAN) control the storage ring VEPP-3. MSV3 is responsible to control magnetic system, RFV3 – RF system, and BEAMV4 provides beam diagnostics. More than one hundred DC poser supplies and two RF systems are controlled via these computers. Odrenok FOTHSCAN provides the beam orbit stabilization during synchrotron radiation generation.

Two Odrenoks (UPO, IPO) control the functioning of the pulse injector. Thirteen crates with electronics are connected to these computers. The electronics control about 100 pulse and DC power supplies.

One Odrenok (CHAN) control the pulse power supplies of the transfer line between the storage ring VEPP-3 and the collider VEPP-4M. Next one (BEAMPO) provides beam diagnostics of all transfer lines.

One Odrenok (CONTROL) is responsible for the temperature and vacuum measurements. There are about 600 points of temperature measurements in all systems of the facility.

One Odrenok (RADIAC) provides the radiation measurements in most dangerous points of the VEPP-4 area.

DATA EXCHANGE

Several processes run simultaneously in each Odrenok to provide operations of different parts of the VEPP-4 facility. Most of the processes need the data from other computers to provide proper operations. The data exchange is shown schematically in Fig.3.

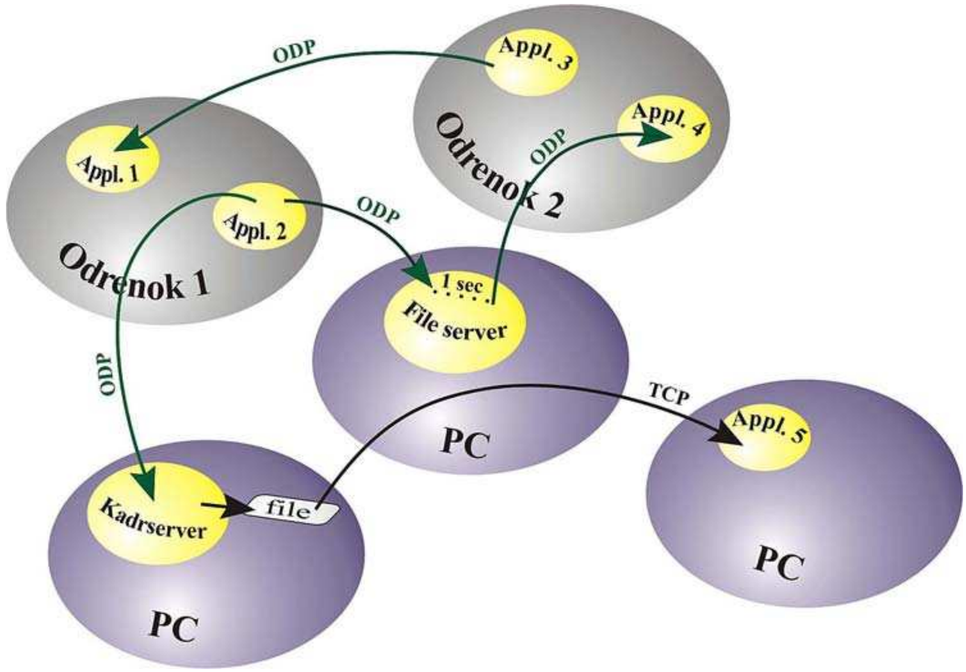

Figure 3: The methods of data exchange in the VEPP-4 control system.

There are three methods for data exchange between the computers.

First method is the direct exchange between the processes. The exchange is supported by a special simple low-level home developed transfer protocol ODP designed for Odrenok computer. This protocol is realised also in PCs connected to the control system for the data exchange between the Odrenok's applications and the PC's applications [6]. This protocol and 10 Mbit Ethernet provide the time of the exchange between different computers about several milliseconds.

Another method is based on the special buffer placed in the Odrenok's file server. This buffer contains the main beam and energy parameters of VEPP-4 facility. The server sends the buffer ones per second as a broadcast message which all the applications can receive.

The third method is using the special data files in one of the PCs. The information from Odrenok computers is translated and is written to files by special program “kadrserver” [6]. The directory with the files is mapped in the all PCs, so any application in any PC can easily read the data. This method is used for data acquisition and archiving [6].

These three methods provide all the data exchanges needed for the automation of VEPP-4 functioning.

AUTOMATION OF THE OPERATIONS

Automation of the storage and acceleration of the beams in VEPP-3

The pulse injector of the VEPP-3 storage ring operates only when VEPP-3 is in injection mode or when it is going to set the injection mode. At that time all the pulse generators are switched on and the automatic process of adjusting of the injector devices starts according the required polarity: changing of the polarity if needed, phase regulation of two sections of LINAC, moving of the converter positron, adjusting of the pulse excitation currents which depend on the temperature of magnetic elements, etc. When VEPP-3 is in acceleration mode or in the experiment the injector stays in sleeping mode. Six applications running in two Odrenok computers provide automation of these operations.

Automation of the beam acceleration in VEPP-3 is provided by five applications running in three computers and one application running in PC.

During beam acceleration from 350 MeV up to 2000 MeV the beam orbit is stabilized according to the measurements from the Beam Position Monitors. After the acceleration is finished the correction of the orbit is done according to the operation mode: producing of synchrotron radiation or extraction to the VEPP-4M ring. It is possible to accumulate one or two bunches in the VEPP-3 ring. So, there is an application which provides an equal accumulation in the both bunches.

After the beam current decrease down to the certain value in the mode of experiments or the accelerated bunches are extracted to the collider VEPP-3 goes to the injection mode automatically.

Automation of the injection to the VEPP-4M

Before the transfer of the beam from VEPP-3 to VEPP-4M all magnetic elements of the pulsed transfer line are automatically adjusted to the certain values of magnetic fields. The required accuracy of adjusting for some pulse bending magnets is better than 100 ppm. It is needed to make several "blank shots" to achieve the required accuracy. The energy of the transfer line can vary in dependence of the energy of the rings from 1.5 GeV up to 1.9 GeV.

After the channel is ready for transfer some preparations are done on VEPP-3 and VEPP-4M. The special bump at the beam orbit in VEPP-3 is prepared in order to keep the beam very closely to the extraction magnet (less than one millimetre). This moment the beam life time may reduce many times in compare with the case of the normal position of the orbit.

At the same time the shift of the beam orbit is performed in VEPP-4M, also the tunes and the coupling are shifted slightly in order to increase the efficiency of the injection.

After described preparations one or two shots is done depending on number of accelerated bunches in the VEPP-3 ring. If it is needed to inject the beams of another polarity the polarity changing operation starts. It takes about five minutes to change the polarity of the pulse transfer line and about twenty minutes to accumulate and accelerate positron bunches in VEPP-3.

Automation of the transfer operations is provided by ten applications running in three Odrenoks and one PC.

The diagram of functioning of the VEPP-4 facility in the mode of experiment with colliding beams is shown in Fig. 4.

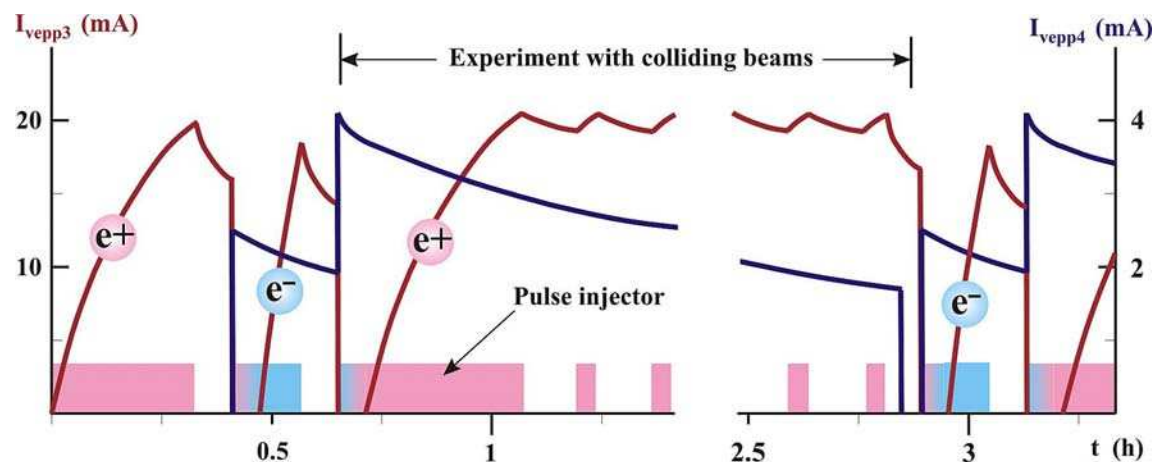

Figure 4: Diagram of the VEPP-4 operations in the mode of the experiment with colliding beams.

Automation of the acceleration in the VEPP-4M

The injected beams can be accelerated (up to 5.3 GeV) or decelerated (down to 1.5 Gev) in VEPP-4 depending on the desired energy of the experiment. The process of acceleration/deceleration is provided by two applications running in one Odrenok and by intellectual DACs [5].

Intellectual DACs have memory in which the values of the node points are loaded. The DACs can provide linear interpolation between the near node points during the time from 200 milliseconds up to 20 minutes. In the case of minutes the relative accuracy between DACs is better than 100 ppm. DACs start operation by broadcast command and finish simultaneously in the defined point or by the stop command. Because of the non laminated yoke of the main magnetic elements of the VEPP-4 ring the acceleration rate is about 10 MeV per second only.

CONCLUSION

The automatic procedures briefly described in the paper provide all the modes of operations on the VEPP-4 facility. In most cases only one operator is needed in the shift.

Nearest next steps of automation are:

- Step-by-step embedding of PCs as graphical consoles and control machines.
- Widening of the set of automated operations.

For example, it is necessary to develop the program for automatic adjusting of the luminosity in experiments with colliding beams.

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