Control of VEPP-4M Magnetic System

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Abstract

The use of BINP-designed intelligent controllers for high-stability magnet power supplies allows us to solve successfully the problem of beam acceleration in the VEPP-4M collider. There are two versions of the controller. The first has sixteen-output sixteen-bit DAC; the second has a nineteen-bit DAC, an error amplifier and a shunt. Both versions have digital linear interpolation and MIL/STD-1553 interfaces. The aspects of the magnetic system control concerning hardware and software are described. Results of a field behavior study in magnetic elements with the use of these distributed intelligent controllers are presented.

1 INTRODUCTION

The VEPP-4M collider provides experiments with electron-positron beams, back-scattered compton γ-quanta and synchrotron radiation. The circumference of the accelerator is 366 m. The beams in the ring are guided by more than 100 dipole magnets, quadrupole lenses and steering magnets.

The collider is an accelerator with an energy range of from 1.8 GeV at injection to 6.0 GeV. Therefore, a simultaneous rise of the magnetic fields by a factor of 2.5 - 3 is necessary for performance of high-energy physics experiments within a range from 4.7 GeV to 5.4 GeV. This beam energy rise is controlled by the Intelligent Device Controllers (IDCs) based on microprocessors.

Control of the IDCs is performed by the CAMAC-embedded ODRENOK computer [1], which is integrated into the VEPP-4 control system [2]. ODRENOK loads predetermined settings into IDCs and controls them by commands via a MIL-1553-B multidrop data bus.

2 MAGNET STRUCTURE CHARACTERISTICS

The magnet system of VEPP-4M consists of arc cells (FODO), dipoles, quadrupoles, sextupoles and octupoles. Auxiliary coils in dipoles, arc cells and steering magnets are used for beam orbit correction. Moreover, quadrupoles have built-in coils for gradient correction. The VEPP-4M magnetic structure is symmetrical relative to the collision point. Table 1 gives an overview of the magnetic system.

Table 1- The VEPP-4 magnetic system

Magnet type	Number of magnets / pow. suppl.	I_{max} , (A)	H_{max} , (kGs)
arc cell (DO, FO)	66 / 3	6400, 550, 170	5.3
dipole	4 / 2	1600	6.6
	2 / 1	1100	14.5
	8 / arc cells	6400	9.5
quadrupole	2 / 1	1500	6.7
	2 / 1	1700	7.5
	14 / 7	200 - 400	2 - 4
	8 / 2	1350	8.1
sextupole	arc cells / 4	500 - 700	
wiggler	2 / 2	2700	
snake	2 / 1	2000	
sextupole	6 / 6	25	
octupole	2 / 2	8	
steering magnet	21 / 21	8	
skew-quadrupole	6 / 6	25	

Most of the elements are controlled by their own power supplies. All the magnets and power supplies have been developed at BINP. The total number of power supplies is about 330.

All arc cells and some of the dipoles are powered by the same power supply. Quadrupole coils (F and D) in the arc cells are used for control of the tunes. The coils of the same type in all arc cells are energized by the same power supply. The ring chromaticity is mainly regulated by the sextupole coils in the arc cells. These coils are powered by four supplies.

3 CONTROL SYSTEM ARCHITECTURE

There are four data buses: two are connected to 16-output IDCs, the others are connected to single-output IDCs. Such configuration permits the use of common commands for IDCs of each type. For example, “write in” command has different format for IDCs of different kind. Thirty remote modules may be connected to each bus.

CAMAC embedded controllers developed at BINP are used to control the data buses. The controllers are located in aperipheral crate connected to ODRENOK through a 1.6 Mbit/s serial link driver and controller [3].

Derivation boxes without protective resistors are used to couple the stubs to the data bus (Fig.2). The length of the stubs is less than 1 m.

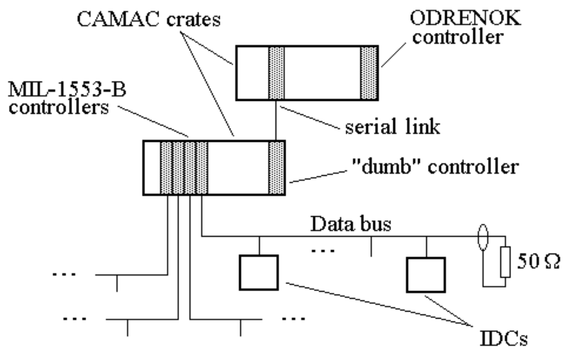

Fig.1 *The configuration of the control system.*

The length of the buses is about 300 m. They pass over all the power supply control rooms around the collider. The transmission rate is 1 Mbit/s. Each bus has a 50 ohms matching resistor at the end.

4 HARDWARE

To control the collider magnetic system, two types of IDCs are used. The first is based on the Intel 8086 microprocessor. It has 16 analog output signals produced by an integrated circuit DAC. These modules are used in order to control low-current power supplies. Fig.2 shows a functional block diagram.

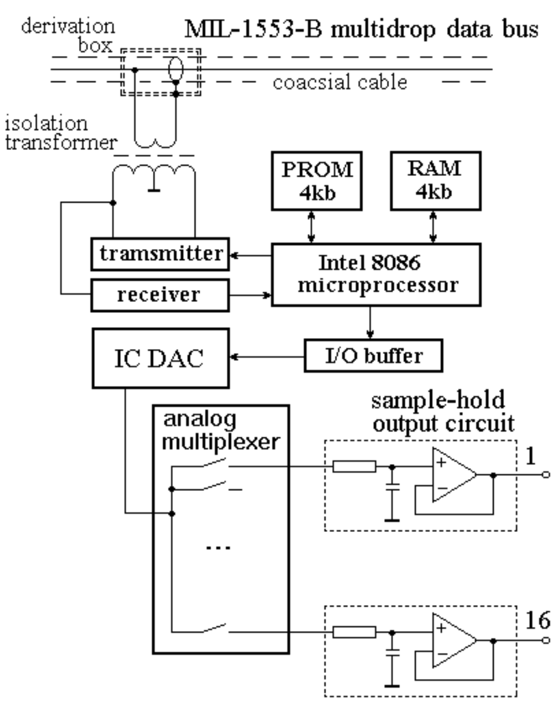

Fig.2 *Block diagram of 16-output DAC.*

The second type is based on the Intel 8035 microcontroller. It has one control output, which provides an amplified error signal. This type is used for the control of middle- and high-current power supplies. A functional block diagram is shown in Fig.3.

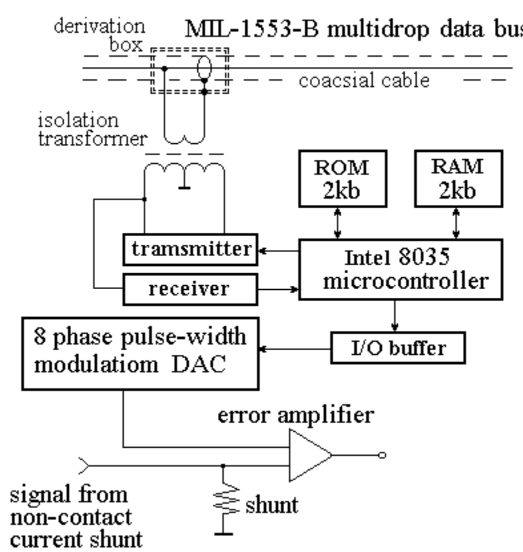

Fig.3 *Block diagram of single-output DAC.*

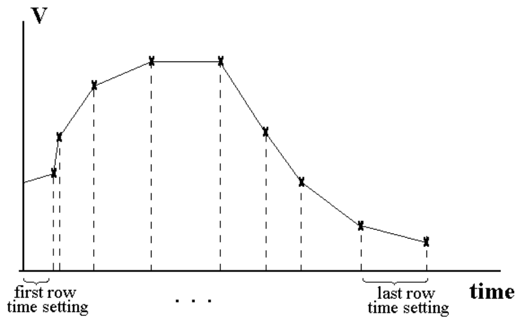

Fig.4 *Example of interpolated output signal*.

Both versions have static internal RAM. A sequence of up to 80 so-called "rows" can be loaded into the RAM. Each "row " consists of 16 settings (or one setting for single-output IDC) and one time setting. There exists the possibility of decreasing the time scale by a factor of 16. That enables control of the "fast" magnetic processes. An example output signal is shown in Fig.4.

In addition, the microprocessor calculates a duration in "tick-portions" for each "row" as a "calculate interpolation" command comes. Sample-hold output circuits are controlled with a frequency of 256 Hz. "Start", "stop" and "continue" commands are simultaneously sent to all IDCs connected to the same data bus for the synchronization of magnet control.

Table 2
Main features of IDCs

Version of IDC		16-output	single-output
Scale (binary)		14 + sign	19
Output voltage (V)		± 6.5	8.192
Error		.01%	.001%
LSB		400 μV	15 μV
Interpolation time between two settings:			
"fast" scale		64 ms - 4 s	
full scale		1 s - 63 s	
Power consumption	+5 V	2 A	2.5 A
	+24 V	0.2 A	0.2 A
	-24 V	0.05 A	0.05 A

5 MAGNET CONTROL

To operate the magnetic system (handling, cycling, beam energy rise) different programs use the Resident Executive Program (REP) [2]. REP loads tables or single settings into the IDCs and sends control commands to IDCs via MIL-1553-B.

All of the magnets are made of non-laminated low-carbon iron. Magnetic field to coil current ratio changes during the energy rise for two reasons. The first is a saturation of magnet yokes. This saturation may be corrected by a corresponding correction of the current. The second reason is associatesd with a delay of magnetic flux penetration into the iron during the process of the energy rise. The deviation of the ratio is determined from the equation (1).

$$d = \left(1 - \frac{H}{H_{st}}\right) \times 100 \quad , \qquad (1)$$

where
H is the dynamic magnetic field,
H_{st} is the statis magnetic field at the same current.

The deviation larger than 0.2 may cause the "death" of the beam. This factor limits the speed of the beam energy rise to 10 - 15 MeV/s, so that it takes 5 - 6 minutes to increase the beam energy from 1.8 GeV to 5.3 GeV.

The use of IDCs allows us to reduce the required time by a factor of 3 - 5. Supplementary intermediate settings are loaded into the IDC's memory to correct individual peculiarities of magnets. These intermediate settings may be defined for each magnet from prior measurements. The magnetic field of each magnet is measured with the use of the same hall-probe. An example of such correction for one magnet is shown in Fig.5.

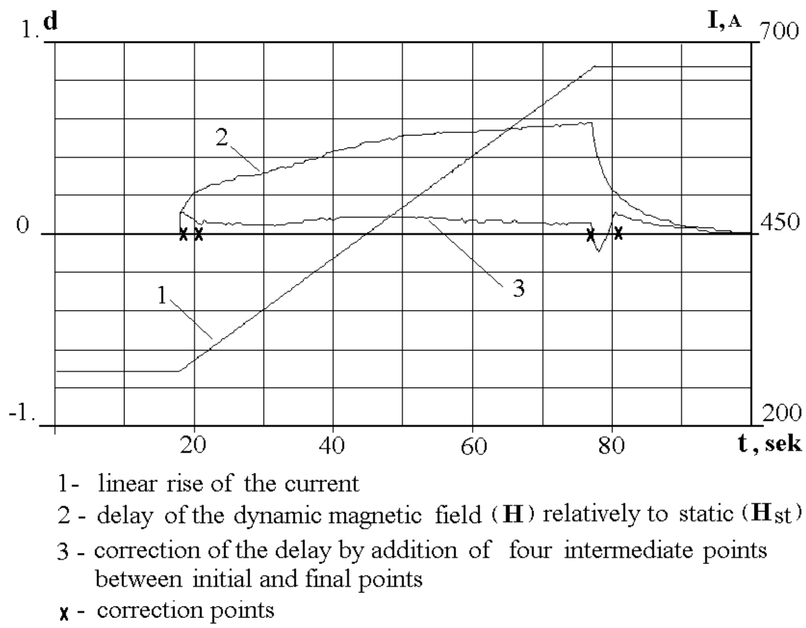

Fig.5 *The magnetic field behavior with coil current rise in EM3 dipole.*

6 REFERENCES

[1] G.Piskunov, Autometria, N4 (1986), p. 32-38 (in Russian).
[2] A.Aleshaev et al., The VEPP-4 Control System, these Proceedings.
[3] V.Kozak, Preprint INP 88-24 (in Russian).