

# SYSTEM OF POWER SUPPLY RIPPLES MEASUREMENT FOR VEPP-2000 COLLIDER\*

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## Abstract

VEPP-2000 collider magnet system consists of about 200 low-current corrections of magnetic fields which powered by independent power sources. During long-term operation of collider power sources ageing occurs. This ageing reveals in output current pulsation increasing with average statistical parameters maintaining. The standard power sources automation system does not allow discovering of such malfunctions which may affect on collider operation stability.

Special automation system was worked out for the aims of the pulsation discovering. In oscillographic regime the system gets measurements of all power sources channels one by one and determines malfunctions automatically carrying out spectrum analysis. The paper describes this technique and measurements results in details.

## POWER SUPPLY

Two types special steering power amplifiers was designed for current supply of VEPP-2000 acceleration facility low-current corrections [1,2]. Each correction magnet is powered by an individual, four-quadrant current source (Power Amplifier) of the PA-6 or PA-20 type. The current sources are made with modern MOSFET transistors as main power elements. The output current of each of the channels is regulated in the range of  $\pm 6A$  and  $\pm 20A$  for PA-6 and PA-20 correspondingly. The regulation error does not exceed 0.1%. The power sources are controlled with special DAC/ADC units.

Table 1: Main Power Amplifier Parameters

Parameter	PA-6	PA-20
Output current	6 A	20 A
Current accuracy	<0.1 %	<0.1 %
Max. output Voltage	120 V	80 V
PWM transmitting freq.	40 kHz	40 kHz
Control/Measurement	DAC/ADC	DAC/ADC

## CONTROL HARDWARE: DAC, ADC

CANDAC-16\*16M and CANADC-40\*24M multi-channel devices are used to control and measure power amplifiers parameters [3]. The devices use modern industrial communication protocol CAN-Bus. Each pair supplies sixteen UM-6 and nine UM-20 amplifiers. Fourteen pairs of the devices serve all direct low-current correction system of VEPP-2000 complex.

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Crates with PA-6 sources are shown on Figure 1.

### CANDAC-16\*16M

- Number of channels - 16
- Bits - 16
- Precision - 0.05%
- Output voltage -  $\pm 10 V$
- Load resistance -  $> 10 k\Omega$

### CANADC-40\*24M

- Number of channels - 40
- Bits - 24
- Integration time - from 1 to 160 ms
- Effective bits (1 ms) - 10
- Effective bits ( $>10$  ms) - 16
- Input voltage -  $\pm 10 V, \pm 1 V$
- Input resistance -  $>10 M\Omega$

ADC can operate in two main modes: Multi-channel Cyclic (all specified channels one by one) and Single-channel Oscilloscope (one specified channel with integration time period).

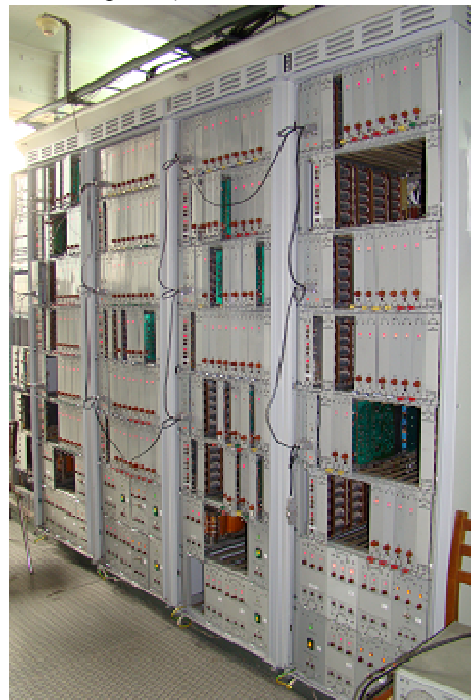


Figure 1: Crates with PA-6 for VEPP-2000 complex.

## SOFTWARE

The software system is based on client-server technique over TCP/IP protocol and has two levels: one hardware

server to handle low-current correction system and multiple GUI client applications.

The server initiates its work by reading all DAC and ADC channels settings from the low-current corrections database. It configures all ADCs to measure current and voltage of each PA one by one in cyclic mode with at least 0.01% accuracy and starts to serve clients. Full cycle of all correction measurements duration (200 current + 200 voltage channels) is about one second. This is sufficient to monitor the system during regular facility operations. But it is not applicable for ripples measurements due to 20 ms ADC integration time because of ADC filters frequencies above 50 Hz.

To measure power amplifiers ripples special client application was designed. It switches ADC to single-channel oscilloscope mode and gets current or voltage oscillogram with 1 ms time step. With fast Fourier transformation (FFT) one can obtain spectrum up to 500 Hz.

### RIPPLE TEST APPLICATION

The main window of the application for automatic Power Amplifiers ripple test is presented at Figure 2. PAs, named by the corresponding magnetic elements, grouped into tree-like list by the placement on accelerator facility and its types. After beginning of auto test procedure the program starts measurement and analysis current and voltage sampling of 1024 oscillogram points for every PA one by one. At the present time every PA test checks four sensitive parameters: a current standard deviation, a current maximum frequency a amplitude, a voltage standard deviation and voltage maximum frequency amplitude.

An operator is allowed to set up appropriate thresholds for each sensitive parameter. If one of them exceeds respective threshold the program marks PA test status as "Failed".

A double click on the PA line opens the new window with sensitive parameters, an oscillogram, a histogram of distribution and a FFT graph on it. This window also allows to the operator to launch new test for this PA (example of the window presented at Figures 3 and 4).

### COMMISSIONING OF THE MEASUREMENT SYSTEM

The ripple measurement system was tested with a signal bringing to the ADC input from special external generator and representing sum of DC and AC signals. The signal models real shape of PA voltage or current, but with well known mean and frequency parameters:

$$I(t) = C + A \cdot \sin(2\pi vt + \varphi),$$

where  $C = 3$  A (DC component),  $A = 0.3$  A (AC amplitude),  $n = 300$  Hz. Figure 3 presents the result of analysis of the test signal. On this picture one can see good agreement with the test parameters. The discrepancies can be explained with relatively low ADC measurement accuracy in such operation mode and low

stability of the internal ADC clock generator. The other test with frequency from 10 to 500 Hz has also given good agreement in results.

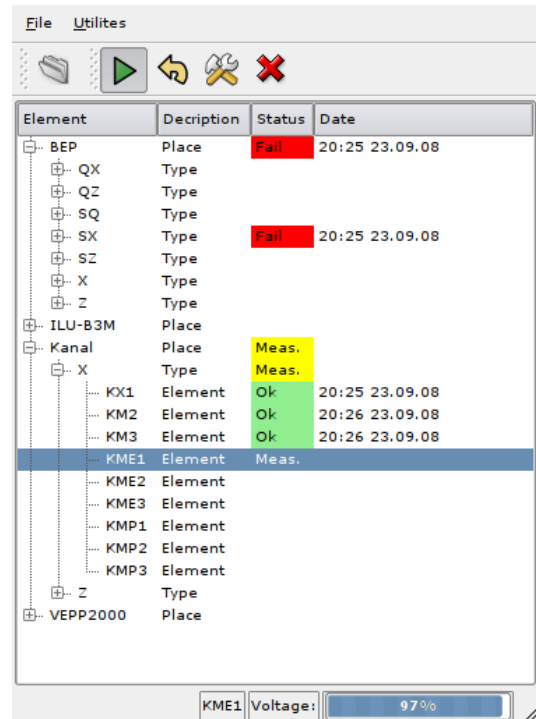


Figure 2: Main window of PA ripples measurement application. KME1 element measurement in progress.

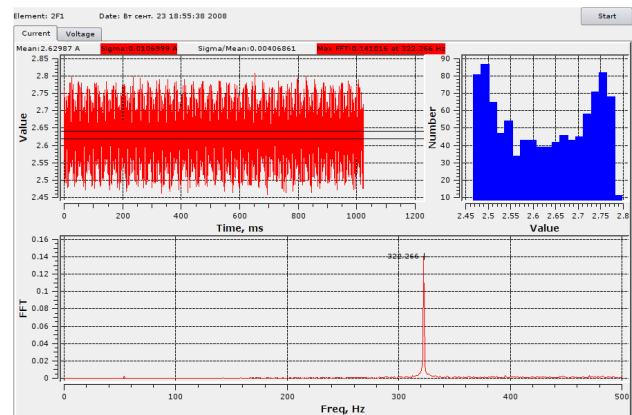


Figure 3: Analysis of the test signal from external generator. Measured values:  $I = 2.63$  A,  $n = 322$  Hz.

### “ROAD” MEASUREMENTS

First runs of the system have shown several (about ten) malfunctioned Power Amplifiers. It's appeared to be quadrupole field corrections in the booster ring BEP. The typical program data analysis is shown on Figure 3.

After detailed investigation with more powerful tools it was carried out that the group of elements is inductively influenced by high current of guide field of the ring. Figure 5 shows oscillogram of this malfunction. On the Figure one can see that the frequency of AC component

exceeds 500Hz, but nevertheless the “mirror” frequency with quite smaller amplitude is detected with confidence (Frequency 422 Hz on Figure 4).

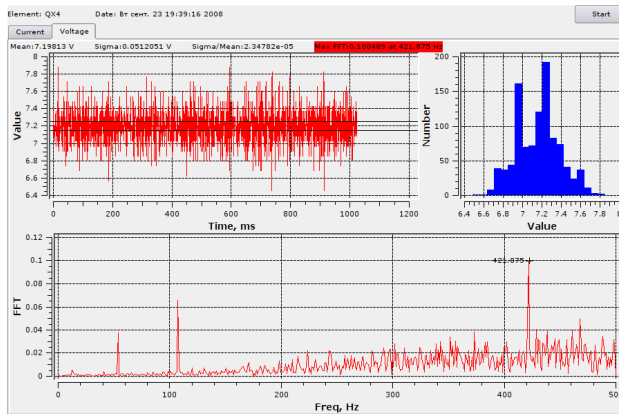


Figure 4: Analysis of the real voltage signal of element QX4. Specific frequencies of 50, 100 and 420 Hz are distinguishing well in voltage spectrum.

The same results of detection of frequencies above 500 Hz were obtained in commissioning tests with the external generator.

This type of malfunction was eliminated by modification of magnetic elements circuit.

## CONCLUSION

The system of ripples measurement for low current corrections of VEPP-2000 collider facility was designed. The main goal of the system is automated measurements of ripple's parameters and detection of malfunctioned Power Amplifiers. The system has limited possibilities (maximum frequency of 500 Hz and accuracy about 0.1%), but nevertheless gives brief information about corrections power supplies status to operators.

The system is based on regular ADCs and represents the client-server software solution over TCP/IP protocol. The analysis of malfunctions is based on statistical and FFT processing of oscillographic data. One full cycle of measurements for all PA takes up about 5 minutes.

Results can be presented in two ways: brief tree-like table and full data analysis for each power amplifier.

At present time the system works at VEPP-2000 collider facility. Further evolution assumes to add new criteria for malfunctions detection.

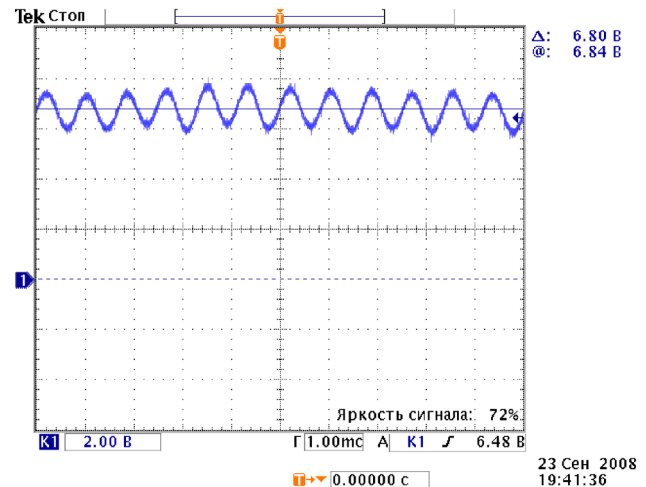


Figure 5: Voltage oscillogram of QX4 Power Amplifier. DC component is 6.8 V; AC amplitude - 1 V, frequency - about 600 Hz.

## REFERENCES

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