POWER SUPPLY SYSTEM FOR CORRECTING MAGNETS OF VEPP-2000 COMPLEX

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Abstract

The closed orbit in the electron-positron storage ring is corrected with the help of correcting windings. Each winding is powered from an individual, four-quadrant current source (power amplifier) of the PA-6 or PA-20 type. The current sources are made with up-to-date MOSFET transistors as main power elements. The output current of each of the channels is regulated in the range of ±6A and ±20A for PA-6 and PA-20, respectively. The regulation error does not exceed 0.1%. The power sources are controlled with destined DAC/ADC units.

INTRODUCTION

In 2000, at BINP SB RAS it was started modernization of the VEPP-2M collider in order to increase its brightness and maximal operating energy up to 2x1GeV, which led to a principally new optical scheme of the new collider (based on the idea of round colliding beams [1]). The new project is referred to as VEPP-2000.

The magnetic system of the accelerating complex VEPP-2000 comprises about 180 low-current elements as follows:

Table 1: The injection complex, including transport lines and the booster ring BEP

Dipole corrections	47
Quadrupole corrections	26
Skew-quadrupole corrections	12
Sextupole corrections	24

Table 2: VEPP-2000 storage ring

Dipole corrections	36
Quadrupole lenses	4
Skew-quadrupole corrections	12
Sextupole corrections	24

The main part of these elements is controlled by current up to 5A. They are powered from the bipolar power amplifiers PA-6. Since these correcting elements differ in active resistance, they were grouped in accordance with voltage drop, which gave five groups with the following output voltage: up to 32V, up to 40V, up to 48V, up to 64V and up to 80V. Each group of amplifiers is powered from an individual mains rectifier. Such grouping makes it possible to avoid differentiating of PA-6 against their output voltages and to make them identical with a maximal output voltage of ±120V.

In addition to the listed corrections, there are about ten dipole corrections in the BEP-VEPP beam-line, which are controlled by current within ±20A. The maximal voltage drop across the correction winding is ±40V. These corrections are powered from bipolar power amplifiers PA-20.

Main parameters of PA-6 and PA-20 are presented in Table 3.

Table 3: Main parameters of PA-6 and PA-20

Parameters	Power Amplifier PA-6	Power Amplifier PA-20
Output current	±6A	±20A
Current accuracy	≤0,1%	≤0,1%
Output voltage	± 120V	± 80V
Control	DAC/ADC	DAC/ADC
Cooling of PA	Air Natural	Air Natural
Cooling of Rack	Air forced	Air forced
Load overcurrent protection	Yes	Yes
Temperature protection	No	Yes

STRUCTURAL DIAGRAM

Fig.1 shows a structural diagram of the power amplifiers PA-6 and PA-20. The output current is regulated with pulse-width modulation of the output voltage of a bridge inverter with a conversion frequency of 40kHz. At the exit of the bridge inverter, there is a second-order filter, which provides suppression of the carrier frequency by 60dB. A feedback loop with a static loop gain of the order of 1000 ensures the required accuracy of conversion. Isodromic regulation provides stability of the system. In a steady state, the regulation turns out to be static relative to the reference-input signal, which allows high regulation accuracy. After the change of the reference-input signal, the system works as a proportional regulator, thus allowing one to avoid over-regulation caused by the delay in the integrator (the integration time constant τ=0,5sec).

Application of the non-stabilized mains rectifiers as bulk power supplies results in the rise of ripples 100Hz and 300Hz harmonics at the exit of the power amplifiers. In order to suppress the ripples, we introduce an additional, faster voltage feedback.

The power amplifiers are equipped with two identical, non-contact current monitors of a compensatory type (DCCT) installed in the output circuit (behind the filter).

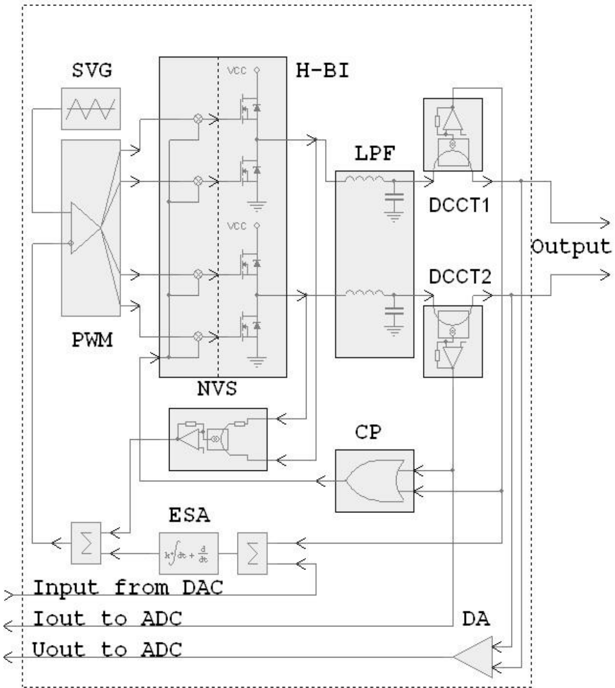

Figure 1: ESA – Error-signal amplifier. SVG – Sawtooth-voltage generator. PWM – Pulse width modulator. H-BI – H-Bridge inverter. LPF – Low-pass filter. DCCT – Noncontact current sensor. NVS – Noncontact voltage sensor. DA – Differential amplifier. CP – Current protection. DAC – Digital-to-Analog converter. ADC – Analog-to-Digital converter.

One of the DCCT is used in the feedback circuit; the other serves as an independent measurer for the control system.

The most frequent failure of correcting elements of large facilities is the uncontrollable contact of the winding to the "ground". In order to prevent failure of the power amplifier because of a load fault, special protection was foreseen for PA-6 and PA-20, to interlock operation of the power amplifier at an excess of the allowable current value in the half-bridge of the inverter. Then, the power amplifier is automatically rerun with a frequency of about 1 Hz. In so doing, the control computer is warned about the protection operation.

Beside the over-current protection, the power amplifier PA-20 has temperature protection. If the radiator has been over-heated, the power source operation is blocked. Then, after cooling, an automatic rerun is performed. In this case, the control computer is also warned.

For controlling purposes, we have foreseen measurement of such values as the load current and output voltage of the power amplifiers. Such measurements allow one to monitor the load resistance value, which permits the software to reveal a faulty element of the winding and to control its temperature.

For convenience in operation, we have foreseen a regime of "hot replacement" of a power amplifier, which is carried out in a working module, without switching OFF of the rack.

CONTROL OF MODULES

There are two variants of a multi-channel system for powering the low-current elements. The first variant includes 8 power amplifiers (Fig.2). Control and monitoring are realized via a special DAC/ADC unit of CAC208, which includes an 8-channel 16-bit DAC, 20-channel 24-bit ADC and input/output register for 8/8 external binary commands. The second variant consist of as many as 16 power amplifiers. A 16-channel 16-bit DAC unit (CANDAC16) and 40-channel 24-bit ADC unit (CANADC40) are used as computer control units [2]. Presence of a CANBUS interface in the control and monitoring units simplifies the link between the power supply module and computer, since data are sent and received by a specialized DAC/ADC module, not by each power amplifier separately.

The modular organization of power supply rack allows more rational usage of bulk power to sources (mains 3-phase matching rectifiers), since the total power consumed is always lower than the maximal possible power (the correcting elements should not work at maximal current simultaneously). Beside the bulk power supply, each module is equipped with an auxiliary power source for DAC/ADC units and control electronics for the power amplifiers.

DESIGN OF THE POWER AMPLIFIERS

The power amplifiers are made under design standard "Vishnya" ("Vishnya-40" and "Vishnya-120" for PA-6 and PA-20, correspondingly). The multi-channel module occupies two 480x240x400 mm crates. A rack with eight "Vishnya" crates can comprise more than 40 of PA-6 channels or up to 20 of PA-20 channels, the air fans of the rack being sufficient for cooling the power electronics.

Since the frequency range of up-to-date MOSFET transistors covers tens of megahertz, we have paid great attention to electromagnetic compatibility of the power amplifiers. For instance, in the power circuits we have applied filters to suppress ripples of the megahertz range. To reduce electromagnetic noise, we manufactured filter chokes mainly with a closed magnetic circuit of the powder material MPP.

RESULTS

The power amplifiers were tested for long-term stability in a heat chamber, in the temperature range of 20÷50°C. Coils of various inductance and resistance as well as short circuit mode were used as loads during the tests. To collect statistic data, we have developed Test-software for monitoring. Analysis of the data collected showed the output current instability to be below 0.1%, which meets the requirements imposed on these sources. The required number of PA-6 power amplifiers has been manufactured by now. About a hundred of them are installed on the injection complex, including the transport lines and BEP; forty of them are installed on the

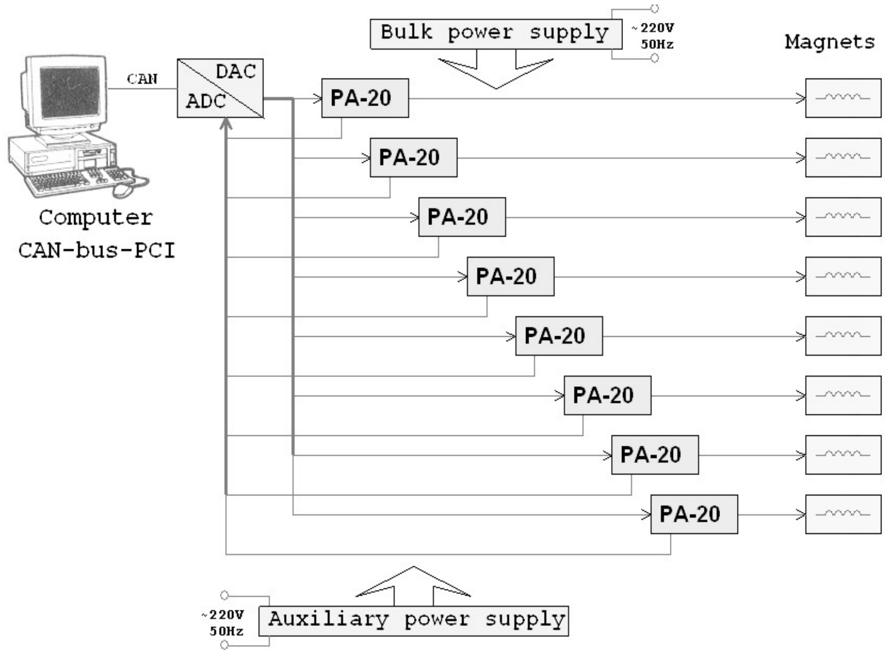

Figure 2: Multichannel system of Power Amplifiers for Magnets.

VEPP-2000 ring. All of them, ready for operation with a beam, are being tried and tested on the complex.

The authors express their gratitude to V.V. Lekhanov, O.A. Proskurina, S.R. Signatullin, and A.K. Tretiakov for their collaboration in this work.

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