PRECISION CURRENT SOURCE OF THE INVERTER TYPE VCH-3000-12 TO POWER MAGNETIC SYSTEMS OF ACCELERATORS AND CHARGED PARTICLE STORAGE RINGS.

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Abstract

The source of the VCH-300-12 type has been developed to power magnetic elements of accelerators and charged particle storage rings with stabilized direct current, providing for setting and controlling the output current level via the computer. Computer-controlled remote switching on and off the Source has also been foreseen as well as monitoring the Source state. Variants of the Source with an output voltage of 8V and 12V and output current of 400A and 300 A have been developed.

Main parameters of the Source are presented in the table 1.

Table 1. Main parameters of the Source.

Parameter	Unit measure	Value
Output voltage	V	8 or 12
Output current	A	400 or 300
Supply voltage	V	220/380 V (3 phases)
Output current instability	%	0,01% (at I_{nom})
Output voltage ripple	%	0,02% (except switching ripple)
Switching ripple 40 kHz	%	0.1%
Dimensions	mm	480x240x400
Weight	kg	16

The Source can be controlled in two modes:
- the remote control mode, from the PC and
- the local control mode, with the buttons on the front board of the Source.

Both modes allow current adjustment in the range of 1 to 300-400A.

The Source is provided with the following kinds of protection:
- against exceeding the maximal admissible output current,
- against more than 20% reduction or loss of supply phase voltage,
- against over-heating of the power unit of the Source,
- against emergency conditions in the load (two channels).

All the protection sensors including the load protection ones are normally closed contacts that are opened in emergency conditions. The Source power supply is switched off at protection operation.

The supply mains have three phases at a linear voltage of 380 V with a neutral conductor. The Source is cooled with air, with the help of fans placed on the front boards of the Inverter and Rectifier units.

Figure 1 shows a simplified functional scheme of the Source. It presents the main elements of the power part and elements of the control loop. The latter consists of three stabilization feedback loops: the main loop for current stabilization (loop A) and two ripple suppression loops (($B_{=}$ and $B_{\sim}$).

The output voltage of amplifier A3 is the reference voltage for loop "$B_{=}$". It is applied to the input of amplifier A4. Feedback loop "$B_{=}$" is closed through the Inverter, Rectifier, LC filter (the resonance frequency is 800 Hz) and the correction circuit R1,R2,C2 and forms the output voltage stabilization loop of the LC filter. Loop "$B_{=}$" fulfils the following functions:

- 10-fold suppression of power mains harmonic ripple in output voltage of the LC filter,
- damping of oscillations of the LC filter due to the resonance in its frequency characteristic, with the help of correction elements R2, R3 and C1, which contributes to provision of stability of main loop for current stabilization "A".

Ripple suppression loop "$B_{\sim}$" consists of the following elements: amplifier-integrator A3, ripple suppression amplifier (RSA) A6, ripple suppression transformer (RST) and differential amplifier A5. The output voltage of amplifier-integrator A2 is the reference voltage for ripple suppression loop A5. It is applied to the A3 input. The amplifier RSA induces a voltage in the RST output winding. This voltage is opposite in phase to the output voltage of the LC filter. The band pass of loop "$B_{\sim}$" in the high frequency range amounts up to 100kHz, which allows much higher amplification in this loop and thus larger efficiency of ripple suppression after RST. The combined ripple suppression coefficient is of the order of 300 to 500, which corresponds to 0,03% from the output voltage of the Source.

It should be noted that the RST transformer is very small, because ripple is preliminarily suppressed by loop "$B_{=}$" and the RST output voltage is of the order of 0,15 V.

Current stabilization loop "A" includes the following elements: error signal amplifier A1, suppression loop "B", current meter DCCT1 (current sensor DCCT HEAD1 and electronics unit DCCT1), and digital-analog converter DAC.

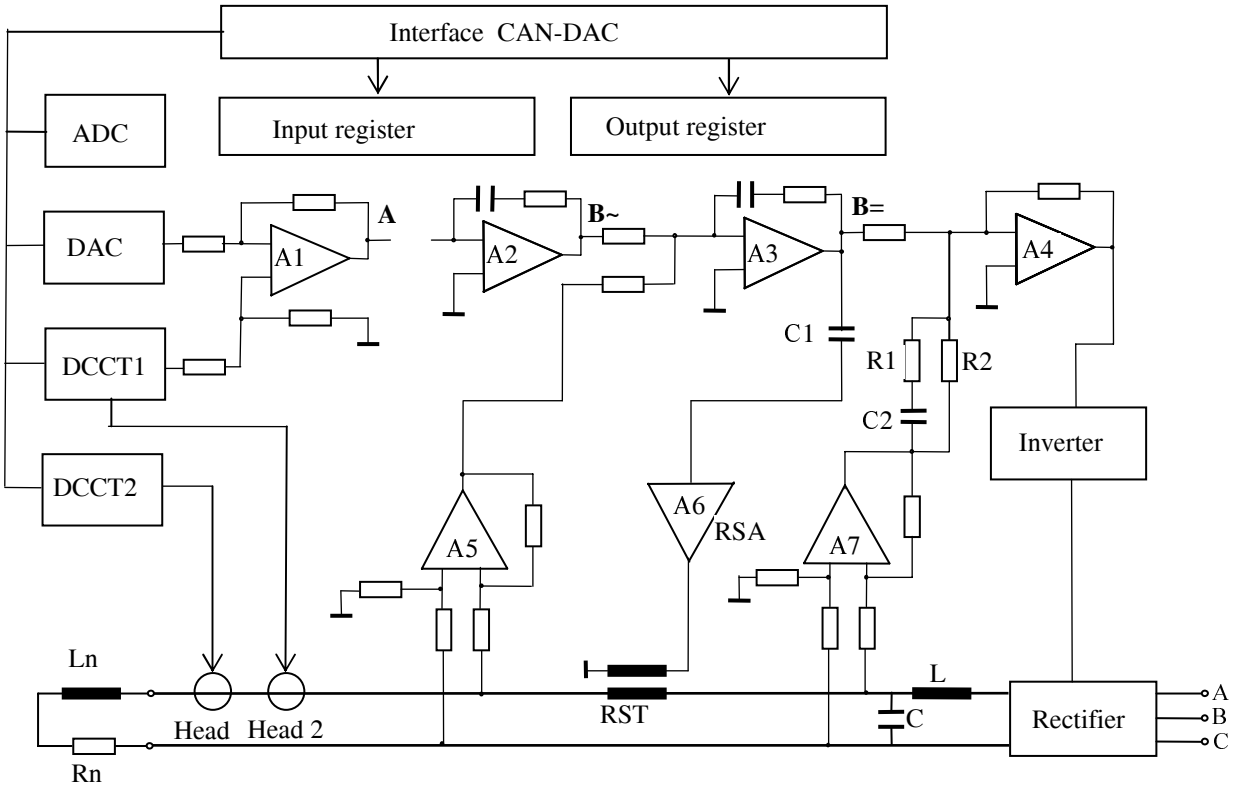

Figure 1: Simplified functional scheme of the Source.

A signal code, specifying the value of output current of the Source, arrives from the control computer to the input of digital-analog converter DAC. The latter converts the digital code to the reference voltage, which is applied to one of the inputs of differential error signal amplifier A1. Non-contacting current meter DCCT1 measures the output current of the Source. The output voltage of DCCT1 is applied to the second input of A1. Amplifier A1 subtracts the DCCT1 voltage from the DAC voltage and amplifies the resulting difference with a factor of 100. The error signal characterizes quality of operation of the whole control loop of the Source. This signal is output on the front board of the Source, for visual monitoring through the "Error" terminal. Amplifier-integrator A2 fulfils further amplification and frequency correction of the error signal. The output signal of A2 is a reference signal for loop "B". The resulting loop of the Source output current feedback has large amplification in the low frequency range from zero to 200 Hz. Namely it provides long-term stability of output current of the Source.

The combined frequency characteristic of the control loop has a drop of 20 db/s in a wide frequency range from several Hz to 100 kHz and thus allows obtaining an aperiodic transition process at current tuning.

Being a current generator, the Source is supposed to have large output resistance. However, that is true only in a relatively narrow frequency range, approximately from zero to 200 Hz, where the loop gain of the control loop is defined by the current stabilization loop. For 200 Hz to 100 kHz, amplification by the voltage stabilization loop prevails and the Source turns gradually from a current generator to a voltage one. That should be kept in mind: the Source can operate with only relatively slow loads such as due to temperature change. However, it cannot operate with fast loads, due to faulty contacts in the load circuit.

The Source is placed in a crate of the "Vishnia" standard and consists of the following units:

The in-feed unit (IFU) comprises switching equipment – a circuit breaker and magnetic starter. After switching-on (manually or remotely), the mains voltage of 220/380 V is rectified by a three-phase bridge and is applied as supply voltage to the inverter. The IFU is equipped with a source protection circuit, which cuts off the power supply in the following conditions:

- loss of any of the power supply phases;
- overheating of radiators in the inverter units and low-voltage units;
- operation of one of the channels of internal protection of the inverter unit;

- operation of one of the two channels of external protections.

The operator can reset the protection after operation using a button on the IFU front board or through the CANDAC unit, in the remote control mode. A toggle switch on the IFU front board is used to switch the source to the remote control mode.

The inverter unit (IU) is intended to transform the power supply voltage to a variable alternating voltage with a frequency of 20 kHz, to power the output power transformer in the unit LVR**.** Voltage is regulated via modulation of length of positive and negative pulses of output power voltage. The inverter is made on power transistors IGBT, assembled by a half-bridge scheme. The inverter has its own protection circuit against overheating of the radiator, over-current and occurrence of through current in the transistor leg of the half-bridge. At operation of any of the protections the signal to switch off the power supply is applied to the IFU unit.

The amplitude of the output voltage of the unit is +/ - 250 V; the maximal output current is up to 20 A.

The low-voltage rectifier unit (LVR) is intended for potential decoupling, transformation with a required transformation ratio, rectification and passive and active filtration of output voltage. To measure output current, the unit is equipped with two heads of non-contacting current meters DCCT1 and DCCT2. The reducing transformer in the unit is made in a single-turn variant with the application of amorphous iron in the magnet core. The rectifier is assembled by a single-phase zero push-pull circuit on field transistors. The LC filter has resonance frequency about 800 Hz. The ripple suppression transformer (RST) is assembled on the SHL16-25 core. The RST is powered from the ripple suppression amplifier (RSA) and allows approximately 30-fold ripple reduction. At joint action of the inverter and transformer feedback circuits, the output voltage ripple of the HV unit in the range of 0 to 300 Hz does not exceed 0.02% from the nominal value. Switching pulsations with a frequency of 40 000Hz can amount 0.1% from the nominal output voltage.

The current stabilization unit (CLM) is intended to close the source output current feedback. The unit contains electronics for two non-contacting current heads DCCT1 and DCCT2 (the heads are located in the LVR unit), a precision current feedback amplifier (A-1), and a plug-in board for correction of current feedback, whose elements are selected in accordance with load parameters.

The Source control unit CDAC20 contains a precision DAC and ADC, an analog signal switching unit for voltage measurement over 8 channels, 8-channel input and output registers for monitoring of the source state and for remote control (including switching on and off) and an interface in the CAN-DAC standard.

Currently make order one hundred Sources VCH-300. The Sources are used on boosters ÂÅÏÏ-5, ÂÝÏÏ-2000 and other installation of BINP.

Now a number of Sources in the Europac PRO units made by the Schroff Company are being developed on the base of the source VCH-300-12:

- a source with parameters similar to those of the RF-300-12 source,

- a two-pole source for superconductive loads with the option of load energy recuperation to the power mains,

- a source with output current up to 1 000 A and output voltage up to 12 V.

The above listed sources, like the VCH-300-12 one, are based on RF transformation of power mains voltage; the sources are cooled with water.