HIGHLY STABLE DC POWER SUPPLIES

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Highly stable ($\pm3 \times 10^{-5} - 10^{-3}$) direct-current power supplies intended predominantly for cyclotron-type accelerators are discussed. All power supplies considered are based on the circuit of the compensated dc stabilizer. Versions of silicon -controlled rectifiers, filters, transducers, and other basic units of the power supplies in question are proposed. Block diagrams of the units discussed are presented. Recommendations on using the units for making power supplies with the necessary characteristics for any particular case are given. Block diagrams of power supplies with several different combinations of their main parameters are presented.

A great variety of direct-current precision stabilizers has been developed at the Laboratory of Nuclear Problems of JINR. For example, the long-operated cyclotron U-120M [1] and JINR Phasotron [2] use stabilizers foı current ratings from a few amperes to 12kA and for voltage ratings from a few volts to a few hundred volts. Current instability and ripple in these stabilizers are of the order of $10^{-3} \div 10^{-5}$.

Now, when necessary, these stabilizers are produced at the Laboratory and installed in the accelerators both operating and under construction. They will also be used in projected accelerators and other set-ups.

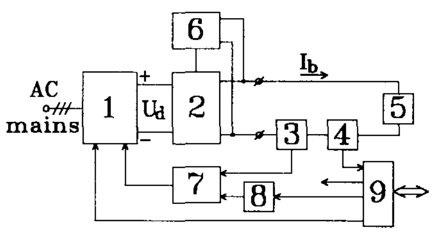

Fig.1. Simplified block diagram of the basic version of the dc stabilizer

A simplified block diagram of a basic version of the current stabilizer is displayed in Fig.1. The stabilizer comprises a controlled rectifying unit 1, a ripple-suppressing filter 2, a current sensor of the load current I_b stabilization circuit 3, a current sensor of the monitoring system 4, a load 5, a voltage ripple sensor 6, a measurement-amplification unit 7, a digital-to-analogue converter (DAC) 8, a unit for local control and communication with the general control system 9. The stabilizer in question is a compensation-type dc stabilizer.

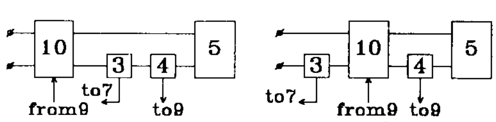

Fig.2. Options of connection of the current reversal unit 10 in the basic version of the current stabilizer

Accelerators and physical set-ups quite often require dc stabilizers that allow changes of the current flow direction in the load (reversal stabilizers). With a current reversal unit 10, the basic version of Fig.1 turns into a reversal dc stabilizer. Contactless switches are supposed to be used in the reversal unit 10. The stabilizer version shown in Fig. 2b has a worse accuracy because the leak currents of the reversal unit 10 flow through current sensor 3. This version can be used if the stabilization error of worse than 10^{-3} is satisfactory. The version shown in Fig. 2a is free of this disadvantage, but in this case the current sensor 3 and the precision DAC 8 must be two polar.

Figure 3 displays versions of the controlled rectifying unit 1: 1.1 is the commutation and protection device, 1.2 is the controlled rectifier, 1.3 is the control device for the rectifier 1.2, 1.4 is the diode rectifier, T is the

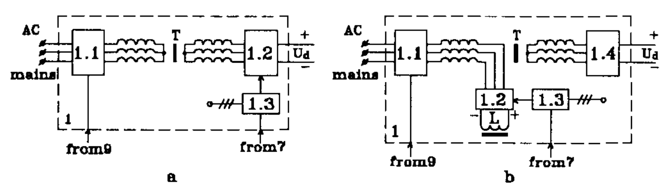

Fig.3. Versions of the controlled rectifying unit 1

power transformer. Version 3a is recommended practically for all cases when the voltage U_d exceeds 10V. Version 3b is preferable for low U_d (below 10V) and under special operation conditions [3].

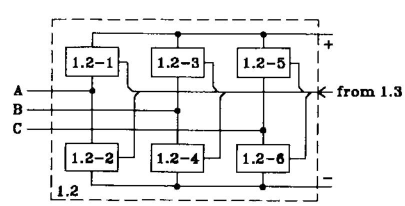

Fig.4. Block diagram of the controlled rectifier 1.2

Figure 4 displays a block diagram of the controlled rectifier 1.2. Power optron thyristors or cascade-connected power and optron thyristors (Fig. 5a and 5b respectively) can be used as controlled rectifiers 1.2-1, ..., 1.2-6. In this version of the controlled rectifier its control device 1.3 does not include pulse transformers, which increases the reliability and manufacturability of the current stabilizer.

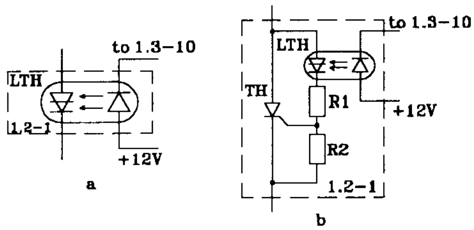

Fig.5. Versions of controlled rectifiers of the unit 1.2

A simplified block diagram of the control device 1.3 is displayed in Fig.6: 1.3-1, ..., 1.3-3 are the units for forming synchronization pulses from voltages of the ac mains phases A, ..., C (3 identical units), 1.3-4, ..., 1.3-9 are the control pulse time delay units (6 identical units), 2.3-10,

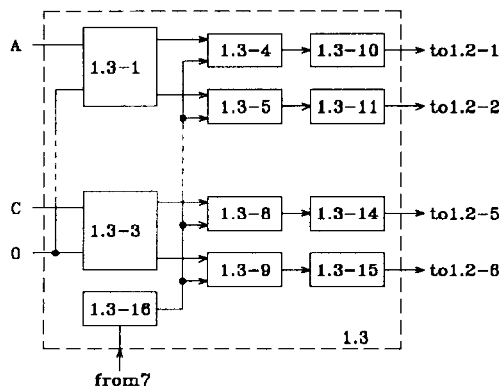

Fig.6. Simplified block diagram of the rectifier control device

..., 1.3-15 are the units for forming pulses to control controlled rectifiers (6 identical units), 1.3-16 is the voltage-controlled frequency generator.

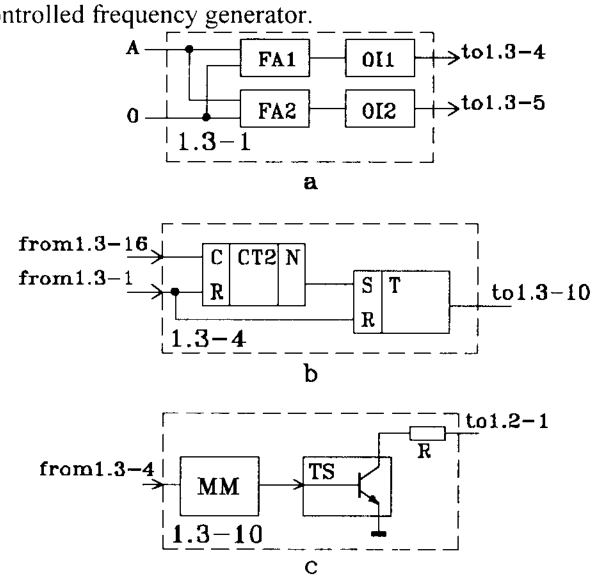

Fig.7. Versions of the units for the control device 1.3

Figure 7 displays versions of the basic units of the control device 1.3. The synchronization pulse formation unit (Fig.7a) has two channels, each containing a pulse forming amplifier and optical isolation (FA1, OI1 in the first channel and FA1, OI2 in the second one). The time delay unit (Fig.7b) comprises a binary counter CT1 and an RS trigger T. The control pulse forming unit (Fig.7c) comprises a monostable multivibrator MM, a transistor switch TS, and a limiting resistor R. Rectangular current pulses produced in this unit are about 4 ms long. Their amplitude must ensure switching-on of the optron thyristors LTH.

The device in question has 6 control channels. In each channel a control pulse with an adjustable time delay with respect to the synchronizing (mains) voltage zero crossing is formed. The adjustable time delay is provided by recording the time interval that is necessary for filling the counter with pulses whose repetition rate is adjusted in a wide range [4].

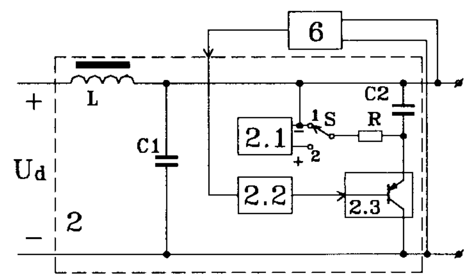

Fig.8. Filter for suppressing ripple of rectified voltage

Figure 8 displays a simplified block diagram of the filter 2 for suppression of rectified voltage ripple. The filter 2 is a combination of the passive (choke L) and active filters [5]. The active filter consists of a constant-voltage power supply 2.1, an amplifier 2.2, and transistor regulator 2.3, a limiting resistor R, correcting capacitors C1 and C2, a commutator S. In addition, the active filter comprises the ripple sensor 6, which is not included in the unit 2. The commutator S allows the power supply 2.1 to be connected in the power circuit of the transistor regulator 2.3 at low voltages (below 5V) across the load 5 in order to maintain operation of the active filter.

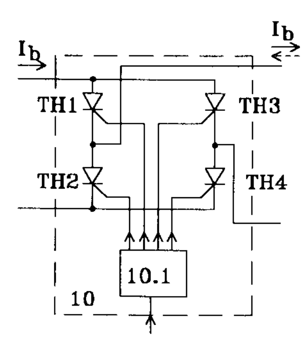

Fig.9. Simplified block diagram of the current reversal unit

The current reversal unit 10 (Fig.9) comprises four thyristor switches (TH1, .., TH4) and a control and protection device 10.1. This device sets the state of the thyristor switches TH1, .., TH4, which determines the current direction in the load. In addition, the device 10.1 ensures reduction of the current I_b to zero by its action on the rectifying unit 1 through the unit 9 at shorting of the reversal unit circuits and at the fulfillment of the command for current reversal in the load [6].

Figure 10 displays two versions of the current sensor 3 in the current stabilization circuit: 3.1 is the magnetizing force (m.g.) nonequilibrium detector and the core saturation detector, 3.2 is the dc amplifier, R_{hs} is the highly stable resistor, W_M and W_C are the measurement and compensation coils respectively, 3.3 is the precision

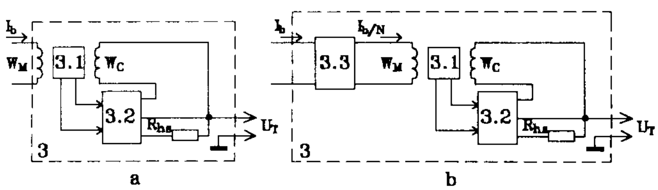

Fig.10. Simplified block diagrams of the current sensor versions for the stabilization circuit

divider for the current I_b (N is the dividing coefficient). One version (Fig.10a) has the conversion error of the order of 10^{-5} for the measured current 100A and lower. As the measured current substantially increases, the conversion error grows larger because heat losses in the highly stable resistor R_{hs} increase. With the precision current divider 3.3 (the other current sensor version, Fig.10b), the conversion error of the order of 10^{-5} keeps up to about 50kA.

The current sensor 3 and the precision current divider 3.3 are based on magnetic comparison of direct currents [7]. Figure 11 displays versions of the dc m.f.

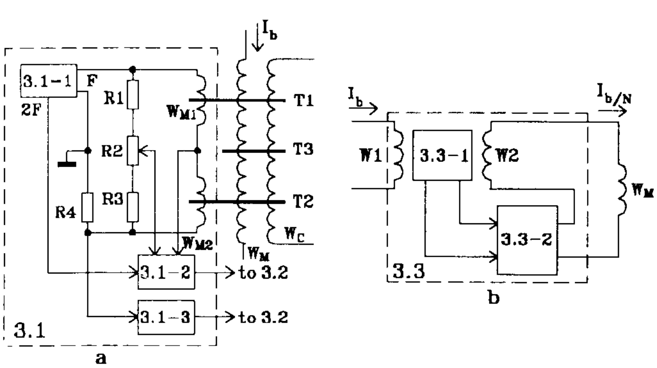

Fig.11. Direct-current m.f. nonequilibrium detector (a) and precision current divider (b)

nonequilibrium detector (Fig.11a) and the precision current divider (Fig.11b): 3.1-1 is the rectangular voltage generator (meander) with the principal frequency F and double frequency 2F outputs, 3.1-2 is the phase-sensitive detector, 3.1-3 is the saturation detector for toroidal working cores T1 and T2, T3 is the toroidal screening core, W_{M1} and W_{M2} are the modulation windings, R1, ..., R4 are resistors, 3.3-1 is the m.f. nonequilibrium detector and the core saturation detector, 3.3-2 is the dc amplifier, W1 and W2 are the primary and secondary windings of the precision current divider. In these versions of the current sensor the m.g. nonequilibrium detectors are based on the magnetic modulator operating on the principle of frequency doubling (magnetic modulator with frequency doubling). A magnetic modulator of this type has a high sensitivity and small zero drift, which results in a small (10^{-5}, as was mentioned above) conversion error of current sensors. The basic data for the current sensor based on magnetic comparison and its units are given in [8, 9].

In conclusion, we point out that owing to their high stability, reliability, and low cost the dc stabilizers developed at the Laboratory of Nuclear Problems of JINR can be effectively used in projected new set-ups.

References

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