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LABORATORY TECHNIQUES

A Power Supply Unit for Discharging the Plasma Electron Source

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Abstract—A power supply unit for discharging a low-temperature plasma generator based on discharge in the crossed electric and magnetic fields is described. The unit operates in a stationary mode with a preset stabilized (±2%) discharge current of up to 0.5 A and in a pulse mode (up to 20 A), taking into account special features of powering gas discharges.

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To date, plasma electron sources (PESs) as an alternative to hot-cathode electron guns have found an application in industry and experimental research [1].

This work describes the structure and principle of operation of the power supply unit (PSU) for discharging the PES based on the discharge in the crossed electric and magnetic fields [2], which is capable of operating in the stationary and pulsed modes.

1. SPECIAL FEATURES OF POWERING PLASMA EMITTERS

In most electron-beam technologies used in machine-building and instrument-making at a beam electron energy of 30–40 keV, it is not necessary to have beam currents of >0.2–0.25 A. The typical PES efficiency of changing-over the electron current from the discharge to the beam is 0.4–0.5 [3]. Hence, the rated discharge current for a significant volume of the beam technologies may be within 0.5 A. Due to the strong dependence of the discharge current on the pressure of the plasma-generating gas, it is necessary to stabilize the discharge current at a required level in the PSU.

It is expedient that the PSU can ensure both the continuous and pulse operation of the PES in order to extend its manufacturing possibilities. It is possible to set off two types of PES pulse operation. In the first case, when the pulse length significantly exceeds the discharge generating and quenching time (from tenths of fractions to units of seconds), the discharge current and, hence, electron beam current differ little in the continuous and pulsed modes. In the second case, when the discharge-current pulse length is comparable with

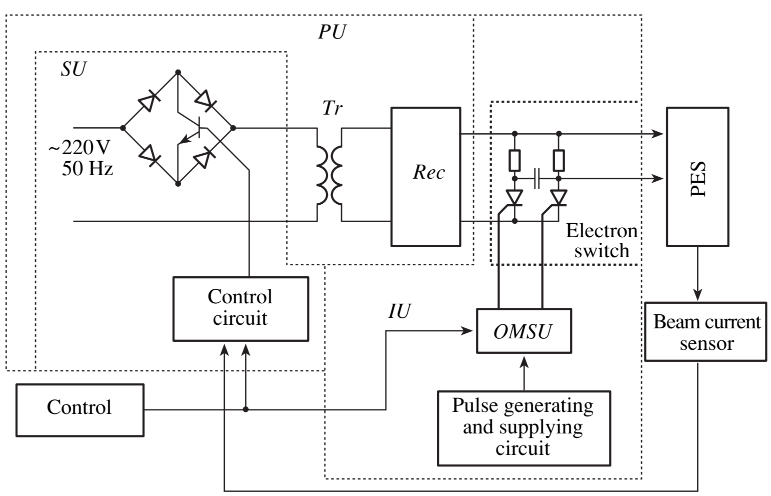

Fig. 1. Block diagram of the discharge power supply unit: (PU) and (IU) power and impulse units, (SU) settings unit, (OMSU) operation mode selection unit, and (Rec) rectifier.

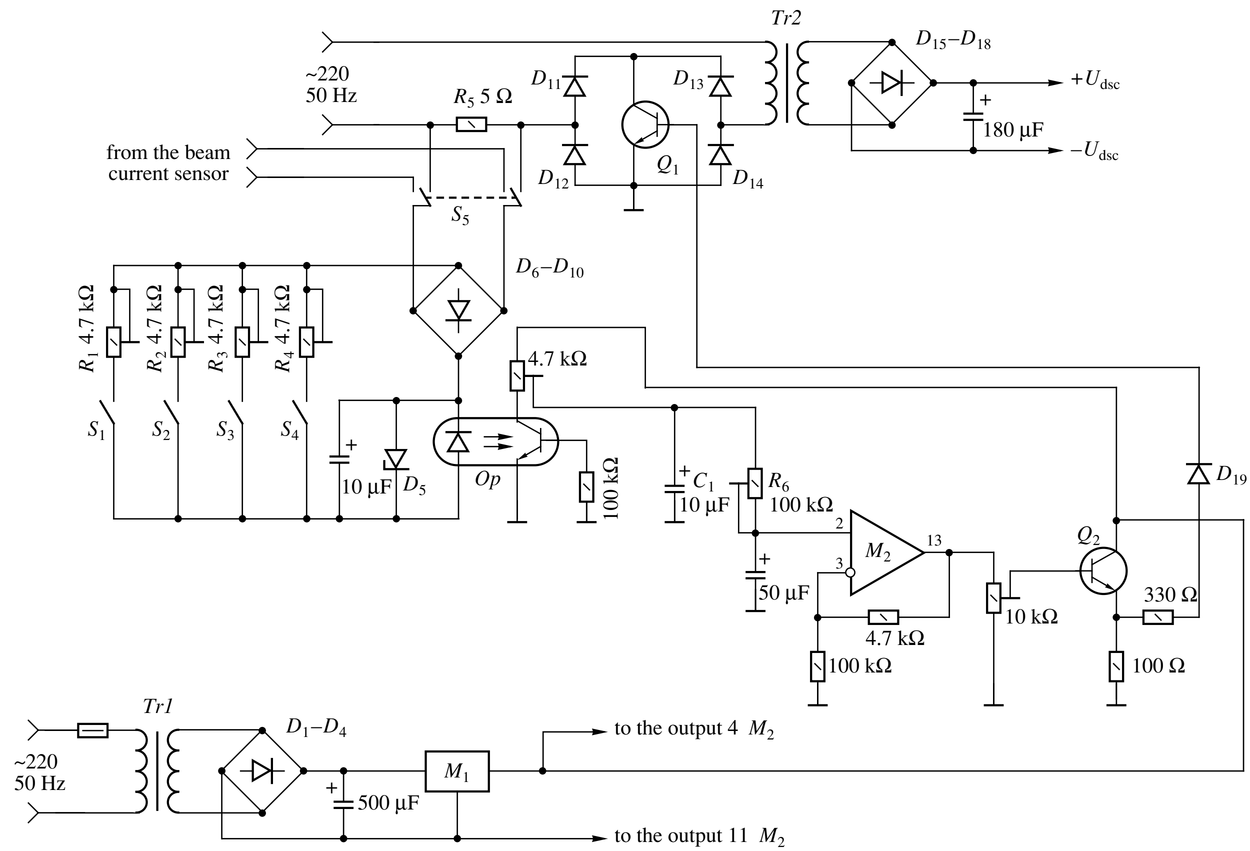

Fig. 2. Schematic diagram of the power unit: (M_1) КР142ЕН8Б, (M_2) КР157УД2, (Q_1) КТ812А, (Q_2) КТ817Г, (Op) АОТ123Б, (D_1–D_4, D_6–D_{10}, D_{19}) КД209Б, (D_5) КС133А, (D_{11}–D_{14}) КД226Д, and (D_{15}–D_{18}) КД210Г.

the lifetime of the abnormal superdense pulse discharge [4], which is several tens of microseconds, the discharge current can reach tens of amperes due to a short-term pressure jump because of plasma-generating gas desorption from walls and electrodes of the discharge chamber [5, 6]. Hence, the capacitance of the rectifier filter should be sufficient for forming these pulses.

2. BLOCK DIAGRAM OF THE PSU

Figure 1 shows a block diagram of the PSU. The power unit (PU) contains settings unit SU, step-up insulating transformer Tr, and rectifier Rec. The PU initiates the discharge at the initial moment and, in the case of the short-term discharge quenching during operation, produces and stabilizes the required discharge-maintenance voltage and automatically regulates the discharge current by controlling the beam current. The operation-mode selection unit (OMSU) ensures PSU operation in the stationary and pulsed modes, depending on the control signal. The pulse unit (PUn) produces a preset number of pulses with the requisite length and frequency. The OMSU and PUn are schematically integrated. A thyristor is used as an electron switch in order to ensure various operation modes of the PES.

3. OPERATION OF THE PSU IN THE STATIONARY MODE

The power unit, the schematic diagram of which is shown in Fig. 2, operates as follows. Upon its switching-on, the discharge in the PES is not formed, the current is not consumed from transformer *Tr2*, and there is no voltage across R_5. The high voltage at output *13* of microcircuit M_2 is applied to the base of transistor Q_1 and completely opens it. As a result, a 900-V voltage is formed across the secondary winding of transformer *Tr2*. While arriving at the anode and cathode of the PES, this voltage initiates discharge in the discharge chamber.

When the discharge is ignited in the PES, the voltage is formed across R_5. The appropriate current with a value determined by operation of switches S_1–S_4, i.e., by resistors R_1–R_4, is applied to optron pair *Op*. The transistor of the optron pair becomes slightly conducting. The voltage at output 13 of microcircuit M_2 decreases, making transistor Q_1 less conducting and thereby limiting the voltage across the primary winding of transformer *Tr2*. The voltage across the secondary winding decreases, reducing the discharge current down to a level selected by resistor R_1. If the discharge is extinguished, transistor Q_1 will be completely enabled. In this case, a 900-V voltage formed across the secondary winding of transformer *Tr2* initiates the discharge with the former current.

Upon initiation of the discharge, the beam is formed in the PES; its current is determined by the discharge current and is at minimum at the initial moment (units of milliamperes). Then, the beam is directed at the joint of the welded product. A linear relation between the beam current in the PES and the discharge current allows one to use the same circuit for stabilizing the beam current. In this case, the signal carrying information on the beam current value is taken from the beam current monitor. For these purposes, upon directing the beam at the joint, one of switches S_1–S_4 closes, thus setting the beam current value, and switch S_5 is changed to stabilize it. The required beam current value becomes steady for 1–1.5 s for the smooth input and output of the crater by using the time-setting circuit (C_1 and R_6).

The proposed circuit of the PSU ensures:

(i) guaranteed initiation of the discharge at the initial moment and in the case of the discharge failure at any moment of the processing cycle at a discharge current of up to 0.5 A;

(ii) stabilization of the preset discharge current (no worse than 2%) or beam current (no worse than 2.5%) and automatic and manual regulation of the current based on the preset beam current; and

(iii) formation of discharge current pulses with a length of up to hundreds of microseconds and an amplitude of up to 20 A with a regulated off-duty factor and pulses of a second length with a current of up to 0.5 A.

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