Electric Power Supplies for Electron-Ion-Plasma Technologies

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Abstract – The paper is devoted to description of two electric power supplies for electron-ion-plasma technologies developed at the Institute of High Current Electronics, SB RAS, and namely: a DC electric power supply with a galvanically insulated output and a pulsed high-voltage supply of the electric substrate displacement. Electric circuits of the supplies are created on the basis of a high-frequency energy converter with a transformerless input using IGBT-transistors. Control, monitoring of operation modes and indication of the main parameters of the described electric power supplies is realized by means of an 8-digit microcontroller. Possibility to imbed into the system an automated control system of technological process is realized. A DC electric power supply has a galvanically insulated output that can be switched on both by the positive polarity with respect to the load (ion supply) and the negative one (magnetron). Both fast and slow arc control are realized for energy minimization in the electric breakdown of the discharge and for efficient target training, respectively. A pulsed high voltage supply generates at its output voltage pulses up to 15 kV with the frequency up to 1 kHz. Fast protection from electrical breakdown is realized as well.

1. Introduction

Recent development of electron-ion-plasma technologies allowed achieving considerable successes in creation of wear-resistant, anticorrosive, decorative and other types of coatings. One of the main problems restraining wide practical application of scientific developments available in this field is absence of accessible electric power supplies meeting modern technical requirements. These requirements are as follows: reliability, independent adjustment and quality of current stabilization, voltage and power, efficient protection from electrical breakdowns and short circuit, possibility of embedding into the automated control system, quality of the consumable network current, high Q-factor, convenient operator interface, etc. A peculiar feature of the electric power supplies for electron-ion-plasma technologies is that their load is the low-pressure discharge plasma that is notable for its extreme instability and availability of fast-going processes essentially changing its characteristics. A power supply intended to excite such discharges should be serviceable in the whole range of powers from units of watts, when the discharge current equals to units of milliamperes, to tens of kilowatts, when the current can be equal to hundreds of amperes. Moreover, the power supply should have a fast and efficient arc protection. These requirements result in considerable complication and rise in price of developments of analogous electric power supplies.

Electric power supplies for vacuum engineering produced abroad, e.g., production of corporations AE (*Advanced Energy Industries, Inc*) or MKS (*MKS Instruments, Inc*) have the price at the level of 400–800 $ for 1 kW of power and higher that restrains their mass distribution in Russian market. At present, outdated electric power supplies containing a network transformer with falling characteristic and a ballast resistor are widely used in Russia. These electric power supplies have large mass-dimensional indexes and low Q-factor. In such supplies, voltage and current stabilization is absent, as a rule, power control and arc protection system are based on thyristors and do not provide necessary speed of the electric power supply switching off at the arc initiation [1].

Therefore, the task related to development and creation of a high-quality electric power supply on a modern element base for electron-ion-plasma technologies satisfying high technical requirements and oriented to Russian market is extremely urgent.

2. Description of a DC electric power supply with galvanically isolated output

Fig. 1 presents the structural diagram of the developed electric power supply. As it seen from the diagram, the three-phase AC network voltage is commutated to the input rectifier that transforms it into the DC voltage. A capacity makes surge control of the rectified network voltage to the required level. Further, the DC voltage enters the input of the DC voltage chopper (LC-filter) that realizes adjustment and stabilization of voltage at the chopper input and current flowing through it. The DC chopper operates at the frequency of 20 kHz. An IGBT-transistor is used as a switch element. The voltage inverter transforms the controlled DC voltage into the AC high-frequency one whereupon it comes to the isolating transformer made on ferrite cores. The output voltage of the high-frequency AC transformer enters the diode rectifier.

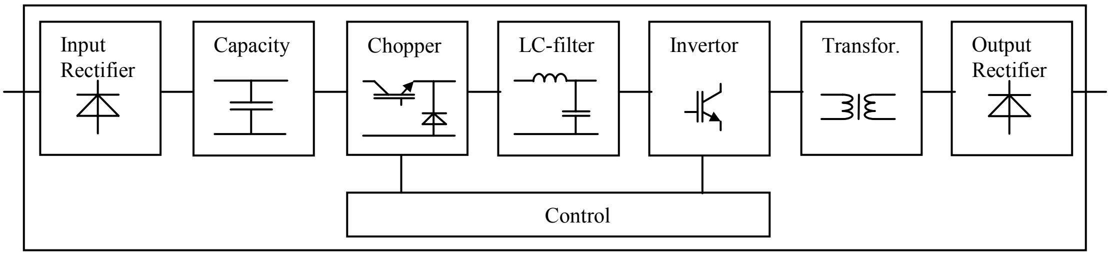

Fig. 1. Structural diagram of the electric power supply with galvanically insulated DC output

Such circuit can be used as a supply of both positive and negative voltages. Thus, combining of functions of two electric power supplies in a similar device allows extending considerably the field of its application in laboratory investigations.

Fig. 2. External view of the electric power supply with isolated DC output

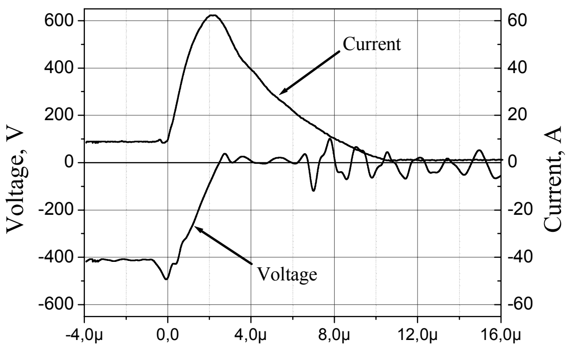

Fig. 3. Oscillogram of magnetron current and voltage at the arc initiation

Fig. 2 presents the external view of the developed electric power supply. Constructively, it is made in a standard 19-inch case of the height 4U (177 mm) and the depth of 460 mm.

The arc control function is developed according to the principle of measurement of the transformer secondary coil current and switching off of the inverter when the current reaches its threshold value [2]. The response time of the arc control system is 2 μs and the energy emitted in the arc is determined by the energy stored in the output rectifier and equals to 10×100 mJ depending on the output voltage. Fig. 3 presents the oscillogram of the magnetron current and voltage at the arc initiation in the fast arc control mode. It is seen that the magnetron discharge with the voltage of 400 V and current of 10 A was burning prior to the arc initiation. Then, during 2 μs from the moment of the arc initiation the discharge voltage dropped to the cathode spot burning voltage and the current increased to 65 A. 2 μs after arc initiation the electric power supply was switched off, the cathode spot current decreased to a critical level and the arc discharge was ceased. Energy contribution into the arc was equal to 80 mJ.

However, at such fast response of the arc control system a problem of the target training arises. To solve this problem, the training mode was included into the device control system. In this mode, the speed of the arc response is slowed down to the level of tens of microseconds. During this time the arc current has the time to increase to a large value and the energy deposited into the arc is enlarged.

It should be noted that the distinctive feature of a circuit solution is absence of a switch element at the circuit output that is usually used to protect a power supply from arcs and short circuits that essentially simplifies the development of the devices with the output voltage exceeding 1 kV [3].

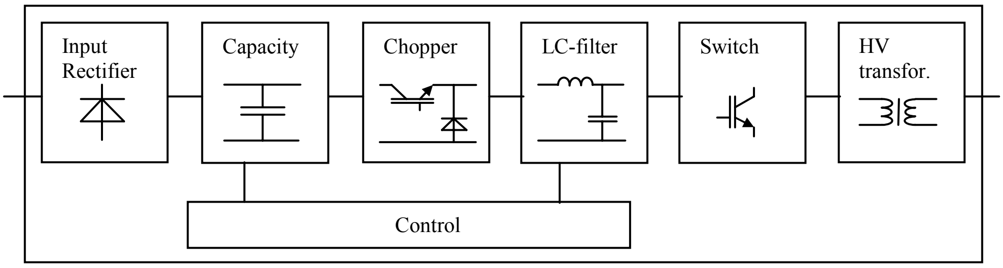

Fig. 4. Structural diagram of the pulsed high-voltage supply of electric substrate displacement

3. Description of a high-voltage pulsed supply of electric substrate displacement

Fig. 4 presents the structural diagram of the developed pulsed high-voltage supply. The input part of the electric circuit of the electric power supply is identical to the one described above (Fig. 1). The difference of the output part is that behind the constant voltage chopper that controls and stabilizes voltage a switch element and a high-voltage transformer made on ferrite cores disposed in the oil-filled case are settled. Maximum voltage at the generator output is 15 kV and pulse current is not higher than 10 A. The IGBT-module commutating the current up to 300 A is used as a switch element.

The external view of the developed pulsed high-voltage supply is presented in Fig. 5. Constructively, it is made in a standard 19-inch case of 6U (267 mm) height and 550 mm depth.

Fig. 5. External view of the pulsed voltage supply of electric substrate displacement

Fig. 6 presents the oscillogram of the substrate current pulse and voltage. The length of the pulse is 30 мs, the voltage amplitude is 4.5 kV, and the average current per pulse is 7 A. Current surge at the pulse edge is explained by the capacitive character of the load.

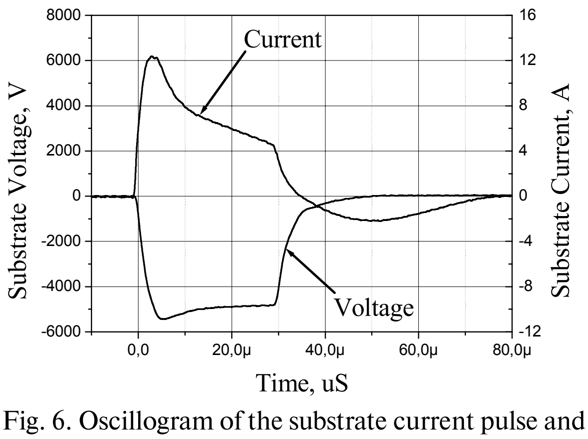

Fig. 6. Oscillogram of the substrate current pulse and voltage

The supply has the arc control system based on the built-in current protection of the IGBT-module. Fig. 7 presents the substrate current oscillogram at the electrical breakdown initiation. It is seen that the arc begins developing 10 μs after the pulse beginning. The current increases up to its critical value of 35 A during 15 μs. At this value the current protection of the IGBT-module operates and thanks to that the arc current stops increasing and drops to zero. The response time of the arc control system is 15 μs, the energy in the arc is approximately equal to 500 mJ.

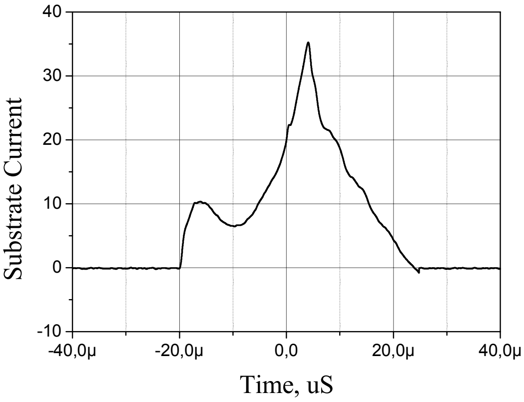

Fig. 7. Oscillogram of the substrate current pulse at electrical breakdown initiation

Application of microcontroller operation by the described electric power supplies makes a possibility to include them into the united system of the vacuum setup automatic control and to have a wide set of engineering adjustments. Such electric power supplies are capable to process the information concerning availability or absence of vacuum in a chamber, cooling in a magnetron or ion source and a number of other parameters. Information concerning the operating parameters and the modes of an electric power supply is screened to the LCD display that can be placed in the vacuum setup control cabinet.

4. Conclusion

To the present day, an actual task for development of electron-ion-plasma technologies is development and creation of electric power supplies on a modern element base satisfying high technical requirements.

The developed electric power supplies allow solving a wide class of tasks on creation of new technologies of electron-ion-plasma surface modification at a modern level.

References

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