Microcontroller Based Multi-Purpose Power Supply for Thin Films Deposition Technologies[1]

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Abstract – The paper contains description of a power supply with a microcontroller that has been developed at the HCEI for electron-ion-plasma technologies. The power supply electric circuit is based on a network transformer and high frequency link with the use of a IGBT. Steering, control and indication of operation modes are realized by means of a eight-bit microcontroller. The power supply has possibility of working to two loads with different volt-ampere characteristics: a magnetron and an ion source. In both operation modes, current and voltage stabilization, fast arc protection with the response time of several microseconds are provided. Coupling with the vacuum installation automatic control system is realized.

1. Introduction

Development of electron-ion-plasma technologies in the last years allowed achieving considerable success in creation of wear-resistance, corrosion-protection, decorative and other types of coatings. One of the serious problems in bringing scientific programs in this field to practical application is creation of power-supply sources meeting modern technical requirements. Characteristic feature of these power supplies is that their load is the low-pressure discharge plasma. It differs by extreme instability, availability of quick-passing processes essentially changing its characteristics [1]. A power supply for excitation of this type of discharges should be able to work in the whole range of powers from units of watt, when discharge current equals to tens of milliamperes, to maximum power of the level of tens of kilowatt when current is optimum. Voltage and current stabilization should be provided taking into account that the last parameter changes by 2–3 orders of magnitude. Moreover, the power supply should have the fast and efficient arc protection.

Power supplies for vacuum technologies manufactured abroad, e.g., products of *Advanced Energy Industries, Inc* have the cost at the level of 1000$ per 1 kW of power that complicates essentialy their proliferation at Russian market. Russian market is orientated to more cheap power supplies including a network transformer with a dropping characteristic and sometimes a ballast resistor for arc protection. Power supplies of these types have large mass-dimensional characteristics and low Q-factor. Voltage and current stabilizaton in them, as a rule, is absent; power control and arc protection system are based on thyristors and provide no necessary velocity of the power supply interruption at the arc initiation.

Therefore, urgency of development and creation of a modern multifunctional power supply on a modern-element base for electron-ion-plasma technologies meeting high technical requirements and orientated to Russian market is obvious.

2. Power Supply Design

The scheme of the power supply having a transformer-free input and a high-frequency converter (inverter) based on IGBT is the most modern for the present day. The merits of this scheme are low mass-dimensional parameters of an isolating transformer and output filter; the drawbacks are the electric circuit complexity, large number of semiconductor elements and, respectively, high cost [2].

Taking into account strict requirements to the power supply for vacuum discharges, forthcoming of modern component parts and high criticality of Russian market to the cost, a power supply was developed having the following structural scheme (Fig. 1).

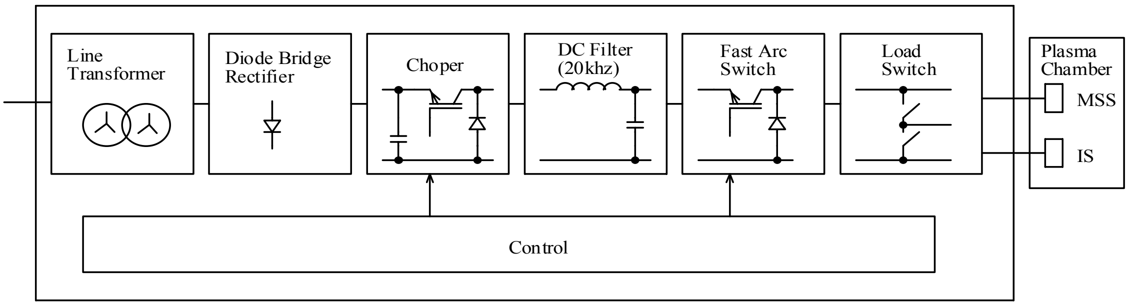

Fig. 1. Power supply structural scheme

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According to the scheme, three-phase network voltage is commutated to a line transformer realizing galvanic decoupling and network voltage increase up to a necessary level. The output transformer voltage is applied to the diode bridge rectifier that forms the negative polarity DC voltage. Further, a chopper and DC filter is situated that realizes voltage or current adjustment and stabilization. A fast arc switch in the mode of operation to the magnetron provides the pulsed operation mode and makes arc protection. In the mode of operation to the ion source it realizes fast arc switching. The load switch realizes the scheme switching between two types of load. A control scheme realizes steering, control and indication of the power supply operation modes.

Figures 2 and 3 present the external view of the power supply and control console, respectively.

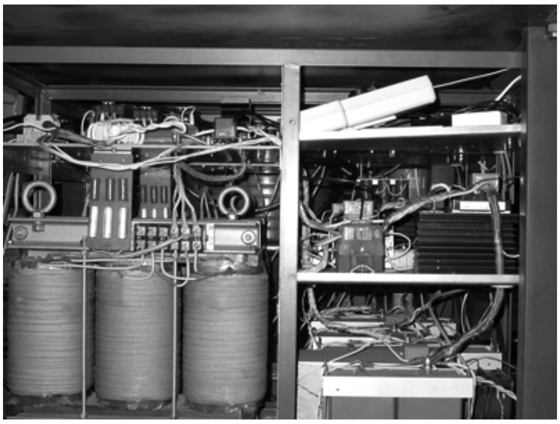

Fig. 2. Power supply external view

Fig. 3. Control console external view

The choice in favour of a low-frequency input transformer is made in favour of simplicity of the power supply force scheme and simple tastes of Russian market to the mass-dimensional parameters of the device.

The DC converter is assembled according to a classical scheme of a step-down converter and serves to control and stabilize voltage or load current using the pulse-width modulation method.

The IGBT-module with the control system including the IGBT driver and the arc controller serves as the fast arc switch. The fast arc switch response to the arc initiation makes up approximately 5 microseconds. It is known that at the arc initiation the discharge voltage drops sharply to the level of ~ 100 V, and then current rise begins with the velocity limited by spurious inductance of current-carrying circuits. The arc controller traces the discharge voltage and in case of its drop generates the signal "arc" to the IGBT driver that closes the transistor breaking the electric circuit between the power supply and discharge. The turn-off time is chosen so that the arc current should decrease to the critical value at which the arc starvation occurs.

Fast arc switching response results in appearance of the target conditioning problem. To solve this problem, the conditioning mode was introduced into the control system. In this mode the velocity of the arc response is decelerated to the level of tens of microseconds. During this time, the arc current rises to a larger value and the energy contributed into the arc increases.

Figure 4 presents the currrent and voltage oscillogram of the magnetron in the operation mode, i.e., in the fast arc switching mode.

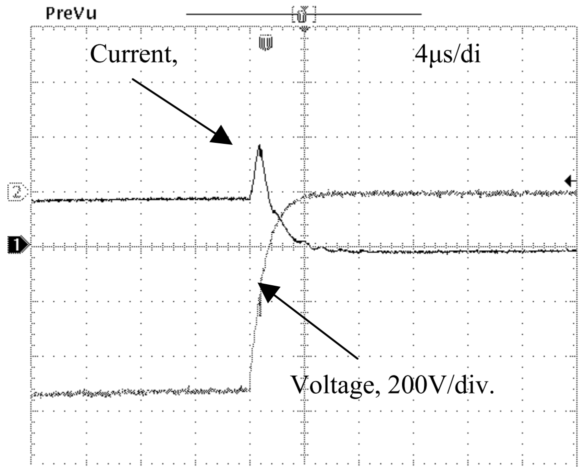

Fig. 4. Current and voltage oscilligram of magnetron in the fast arc switching mode

It is seen that before the arc initiation, a 730-V, 20-A magnetron discharge was burning. At a definite moment of time, the voltage drops sharply and the current begins to increase. The arc controller processes the information and in 5 μs gives the blocking signal to the IGBT driver closing it. The arc current increases to 40 A and energy deposition to the arc makes up several tens of millijoules.

Figure 5 presents the current and voltage oscillogram of the magnetron in the training mode. It is seen from the oscillogram that afer the arc initiation the fast arc switching system introduces a 40-μs long turning-off delay of the power supply that results in the arc current increase to 130 A. Hence, energy delivered into the arc increases by an order of magnitude, magnetron conditioning occupies less time and becomes more efficient.

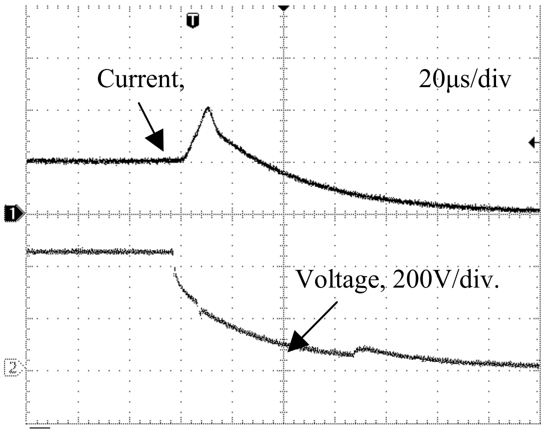

Fig. 5. Current and voltage oscillogram of magnetron in the training mode

Figure 6. presents the current and voltage oscillogram of the ion source at the arc initiation.

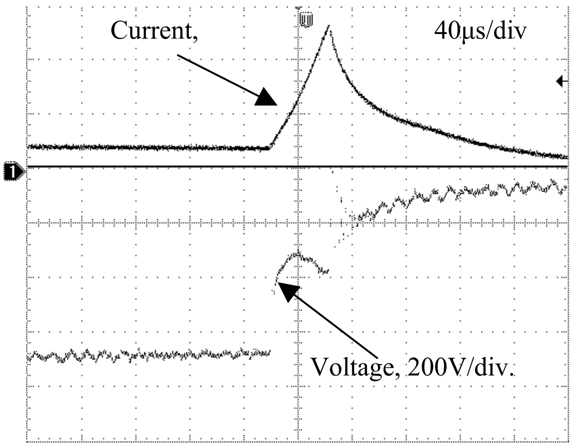

Fig. 6. Current and voltage oscillogram of ion source at the arc initiation

The response time of the fast arc switching system makes up 10 μs allowing the arc current increasing up to 4 A. The time during which the power supply is turned-off makes up 300 μs. During this time the arc has time to starve.

Microcontroller steering of the power supply gives possibility to include it into the system of automated vacuum installation control and to have a wide set of engineering adjustments.

The power supply of this type processes information about vacuum availability or absence in the chamber, cooling in the magnetron and ion source and a series of other parameters. In the engineer mode, about 50 adjustments are envisaged allowing the operator to set the upper and lower limits of the load current and voltage, limits and step of changing the frequency of pulses and their length etc. Information about necessary parameters and operation modes of the power supply is shown at a liquid-crystalline display of the remote control console placed in the vacuum installation control cabinet.

3. Conclusion

By the present, development and creation of power supplies on a modern element base is an actual task for development of electron-ion-plasma technologies in Russian science.

This paper describes the power supply created at the Institute of High Current Electronics. The aim of the development is providing Russian market with a competitive product having different functional possibilities and high technicoeconomic activities.

References

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