Dynamic Modes Modeling in the Power Supply System of Magnetron Generators Group

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***Abstract*— Industrial electrotechnological installations with the distributed microwave energy supply can incorporate several microwave generators on the packaged type magnetrons. At the same time, for the unification purpose electrotechnological installations designers complete each microwave generator with its own power supply. On the one hand, such solution allows to change each microwave generators operating mode quickly, on the other hand, demands the corresponding number of high-voltage blocks that doesn't promote optimum mass-dimensional and cost realization. In this regard the problem of the centralized power supply system creation for the packaged magnetrons group, having fast fine tuning potential of each device operating mode on anode chains, is relevant. The article deals with such system construction and functioning features. For dynamic modes research of the imitating model in the environment of MATLAB with a Simulink extension package is developed. According to the virtual experiments results, automatic regulator parameters influence the on transition processes quality in the three packaged magnetron power supply system is verified.**

***Keywords*— magnetron; power supplies; dynamic modes; simulation**

I. Introduction

For microwave energy sources creation there is wide scale of electronic devices now. For a number of reasons magnetrons with different magnetic field creation systems are mostly used [1, 2]. In the electronic equipment manufacturers catalogs the packaged magnetrons (with the built-in magnets) and the magnetrons with electromagnets are presented. Also there are magnetrons with the combined magnetic system.

Packaged magnetron functioning is carried out by means of a two source power supply system, one of which carries out cathode heat, another serves for anode circuit supply. The magnetron with an electromagnet requires an electromagnet current adjustment possibility source.

The industrial electrotechnological installations using microwave fluctuations energy can incorporate several magnetron generators [3]. In distributed microwave energy supply systems the packaged magnetrons are often used.

In the existing installations microwave generators output power adjustment on the packaged type magnetrons is carried out due to voltage supply duration change on the magnetron anode circuit. This way of adjustment has a number of essential shortcomings, one of which – impossibility of the microwave energy dosed supply on the processed object. In some articles [4, 5] the possibility of the packaged magnetron output power regulation due to anode voltage change is shown.

The packaged magnetrons have electric characteristics variation even in similar models. It is caused by the permanent magnets characteristics technological variation, included in the packaged magnetron design. Therefore for the setting necessary microwave generators operating mode while the anode circuits centralized supply it is necessary to carry out each magnetron automatic fine tuning.

II. Theoretical Positions

The magnetron operating mode by an anode circuit is determined by the volt-ampere characteristic intersection point of the magnetron and the anode supply source external characteristic.

A set of approximate magnetron current-voltage characteristics or I-V curves as shown in Fig. 1 is used for analysis of the magnetron generator operation.

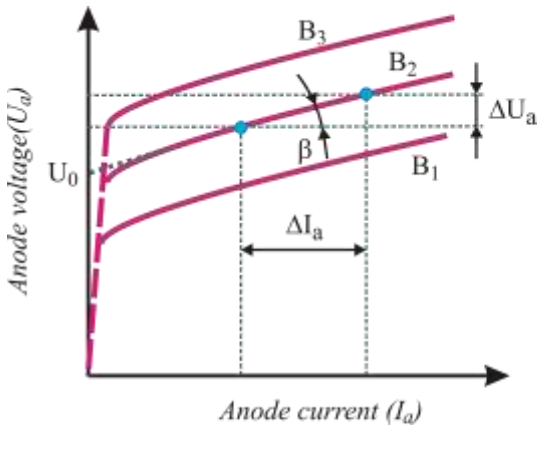

Fig. 1. I-V curves of a magnetron considering different levels of the magnetic field density (provided that $B_1<B_2<B_3$)

I-V curve of a magnetron starts with the abrupt region shown by the dotted line. The region with a small inclination from the I-axis representing the radiation mode of a magnetron follows after the bend point. In the area of anode voltages lesser than threshold voltage ($U_a<U_0$) synchronism conditions between the charge carriers and the high-frequency field are not met, therefore oscillations and anode current are not being induced. Self-excitation of a magnetron and sudden increase in anode current happen as soon as anode voltage reaches the threshold. Afterwards a small change of the anode voltage U_a leads to drastic changes in the anode current I_a amount of which is defined by the cathode emission capacity.

Magnetron important parameter is its dynamic resistance which is defined by a formula

$$R_d = \Delta U_a / \Delta I_a = tg\beta \, . \tag{1}$$

In the study of power supplies for microwave installations, the magnetron is represented as a simple model that consists of a series-connected ideal diode with a threshold voltage and a resistor whose value corresponds to the dynamic resistance of the magnetron [6] – [8].

I-V curve of the magnetron at such piece-linear approximation takes the form

$$U_a = R_d \cdot I_a + U_0 \, , \tag{2}$$

where R_d, U_0 – respectively the dynamic resistance and threshold voltage of the magnetron.

The external characteristic of anode supply source can be presented as follows

$$U_a = E - R_s \cdot I_a \, , \tag{3}$$

where E, R_s – EMF and internal resistance of the power supply respectively.

From (2) and (3) we will receive equation for anode current definition

$$I_a = (E - U_0)/(R_s + R_d) \, . \tag{4}$$

Thus, the required anode current value can be received by an anode supply source EMF change or its internal resistance.

The magnetron operating mode control principles are in Fig. 2 and 3.

At a fixed EMF value a magnetron operating mode corresponding change can be received by the inclination change of the power supply external characteristic. One of solutions of this task is inclusion in an anode supply curcuit every additional resistance magnetrons. It is clear, that this method doesn't allow to change quickly. Magnetrons operating mode change-over requires installation shutdown that can be impossible at various technological processes. It is obvious, for anode currents preset values achievement it is necessary to increase the power supply EMF. Besides, additional resistance presence will lead to power additional losses.

With a fixed tilt of the external characteristic of the power source, its parallel movement leads to a change the magnetron operating mode.

The problem of magnetron group operating mode control can be solved by the inclusion in an each magnetron anode curcuit the additional power supply. Such decision seems perspective as it allows to adjust each magnetron generator in a group quickly to the required operating mode and can be settled by electric equipment with weight, dimensions and cost will be less than similar indicators of individual power supplies installations.

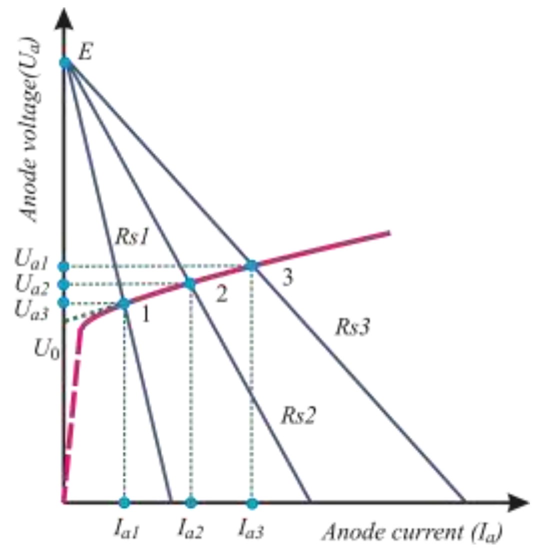

Fig. 2. The packaged magnetron operating mode control by a source internal resistance change ($R_{S1}>R_{S2}>R_{S3}$)

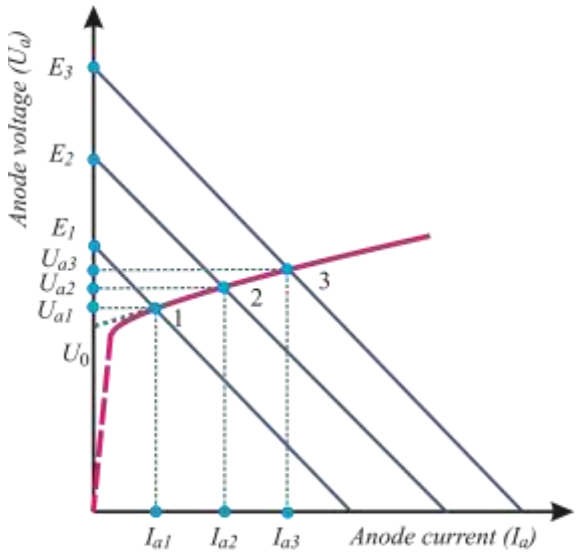

Fig. 3. The packaged magnetron operating mode control by a source EMF change *($E_1>E_2>E_3$)*

III. The Power Supply System Simulation Model

Studying of processes in an electrotechnical complex including power sources, semiconductor converters and a large number of inductive and capacitor elements represents quite a difficult task. The mathematical model describing such a difficult complex represents the high order nonlinear differential equations system. Therefore simulation modeling in the environment of MATLAB with a Simulink extension package is applied to magnetron group dynamic modes research in the power supply system.

The scheme of simulation model for three magnetron generators is shown in Fig. 4. Each generator is presented by the MG subsystem having the control input In1 for giving of the setting influence of Reference_Id, information outputs Out1, Out2 for voltaddition voltage and anode current observation. Power inputs Conn1, Conn2 of the MG subsystems are connected to the DC Power System block outputs which imitates a high-voltage source of constant voltage. When modeling the DC Power System block has been settled in the form of Three-Phase Source and Universal Bridge blocks from SimPowerSystem library. The linear voltage of the three-phase power supply was 3500 V, inductance and active resistance – 2,5 H and 56 Ω respectively.

The scheme of the MG subsystem is presented in Fig. 5. The magnetron is presented in the form of series connected Diode, Rdin and DC Voltage Source blocks. The the additional power supply is modelled by the Controlled Voltage Source block.

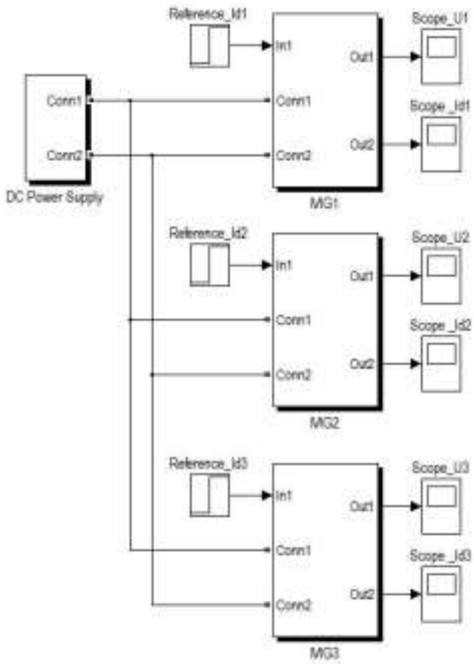

Fig. 4. Simulation model scheme for a transition processes research of in a three magnetron generators power supply system

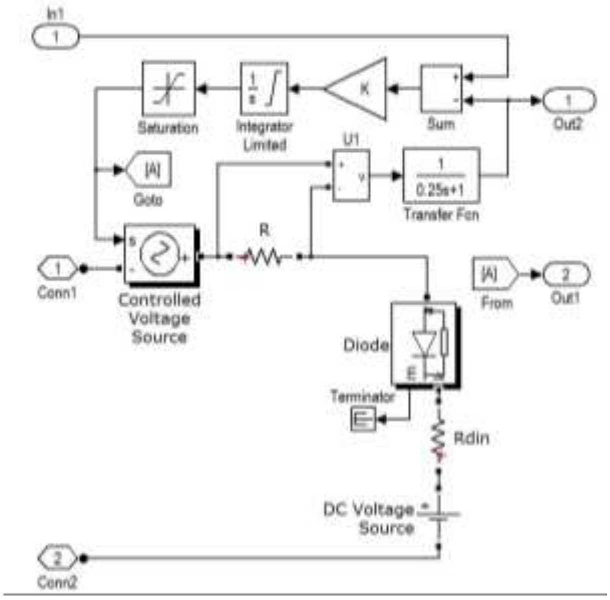

Fig. 5. The magnetron generator simulating model with a additional power supply in an anode curcuit

For measurement of anode current the resistor R with voltage via U1 measuring instrument and via the Transfer Fcn block simulating the low frequencies filter, goes to one of comparison element input (Sum block). To the other input of this element the signal, setting the required value of anode current, goes. The error signal appears on the integrated regulator which output signal via the restriction block Saturation is given to the input of the Controlled Voltage Source block.

In Fig. 6–8 the results of transition processes research in a power supply system of the Toshiba magnetrons E3328 with 3 kW power are presented [9]. According to these magnetrons parameters while modelling the threshold voltage of 4500 V, dynamic resistance of 200 Ω are accepted.

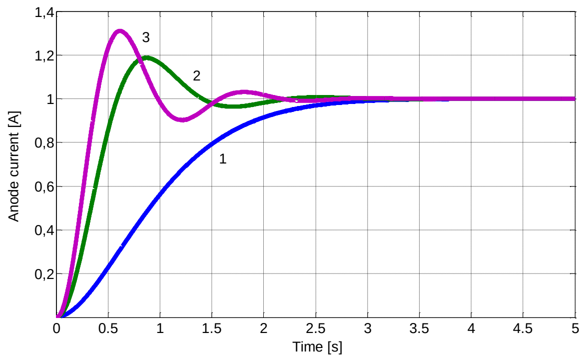

Fig. 6. . Charts of the magnetron anode current change at various values of the integrated regulator coefficient: 1000 s^{-1} (1); 4000 s^{-1} (2); 8000 s^{-1} (3)

From charts in Fig. 6 it is seen that the transition processes quality while magnetron operating mode depends on integrated regulator coefficient significantly. Besides the dynamic modes character is influenced by constant voltage source parameters.

Charts in Fig. 7–8 are done while situation modeling of a 5 second interval sequential nominal mode start of three magnetrons is made. The integrated regulator coefficient was equal 2000 s^{-1}.

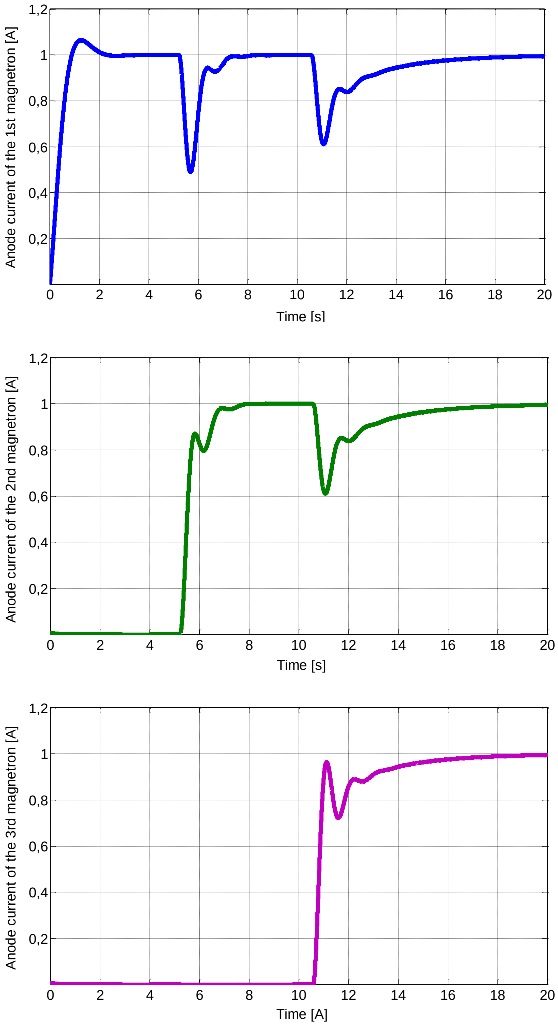

Fig. 7. Charts of the magnetron anode current change at sequential start process

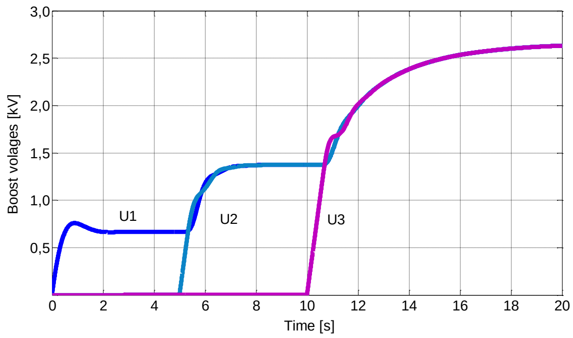

Fig. 8. Charts of the additional power supplies voltage change at sequential start process of magnetrons

The centralized power supply voltage depends on its load current. Therefore, each subsequent start of the magnetron leads to a decrease in the value of common buses voltage and a corresponding increase in the booster voltage. At the same time, a droop is observed on the graph of the current of the already working magnetron, which is eliminated by the operation of the automatic control loop. However, when the voltage of the anode power supply decreases, the duration of the transient process increases.

IV. Conclsion

The power supply system of magnetron generators group represents a complex electrotechnical set, its modeling requires modern software products.

The simulation model research in the environment of MATLAB with a Simulink extension package is developed for a dynamic modes research in this system.

The results of virtual experiments show that automatic regulator parameters and centralized supply source parameters influence on quality of transition processes.

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