REQUIREMENTS TO THE ELECTRICAL DISCHARGE SYSTEM USED IN THE PLASMA-WAVE SYSTEM

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The electrical circuit creating a pulse arc is analyzed. The requirements to the elements of an electrical circuit in the electrical discharge circuit applied in the plasma-wave system are considered [1]. For analysis a discharge gap as a loading in the similar circuits is offered. The experience of practical realization of the circuit under consideration is given. Dynamics of an energy release in the channel of a pulse arc being characteristic for the chosen discharge circuit is experimentally established.

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1. INTRODUCTION

Requirements to the electrical discharge system in the plasma-wave system (below PWS) are determined proceeding from the specific features of the loading in the form of a gas discharge gap and from the task of effective and fast elevation of a gas temperature. Among basic factors of the loading determining the performance of elements of the discharge system one can consider a nonlinear voltage-current characteristic of a discharge channel, a dependence of a distance between the electrodes as well as a dependence of electrode materials. It leads to the change of distribution of the voltage fall values in various parts of the electrical circuit.

The above-mentioned factors determine, first of all, maximally allowed values of the active resistance of electrical circuit elements. Due to defining of a ratio between the loading resistance and the resistance of the electrical circuit elements the required power balance in the discharge circuit is achieved, that creates the preconditions for an effective using of the electrical discharge energy. Also, it is necessary to take into account the properties of circuit elements, which can considerably influence on the rate of heating with a current. To realize an insignificant energy input in the course of arc starting with the use of a pulse transformer as a high-voltage source, the requirements put to it are again caused by specific properties of the loading. The later consist in the dependence of the arcing delay time on the value of the excess voltage on the loading.

Besides, the specificity of discharge realization in the plasma-wave system is caused by the requirement of fast establishment of a condition of a quasi- equilibrium thermodynamic gas state in the positive column of the pulse arc. Basing on the study of mechanisms of break-down and discharge development in gases the conditions of discharge realization in the given device were chosen. These conditions consist in the following. The high-voltage pulse should supply a spark break-down of the gas-filled discharge gap. The further development of a discharge should occur at a low voltage on electrodes. The power of a low- voltage source should supply a high current flowing up to the moment of achievement of a quasi-equilibrium thermodynamic state of the discharge gas. Thus, the value of the energy spent for the spark break-down should be as a minimum by the order of magnitude lower than the energy release during the short-term arcing.

With respect to the plasma-wave system the total duration of the discharge should be not more than $5 \cdot 10^{-5}$ s, thus the required value of the released energy for this period should be not less than 10 J. The voltage on electrodes of the discharge gap during pulsed arcing should insignificantly differ from the discharge voltage of stationary arcs.

2. METHODS OF ANALYSIS OF A SPARK GAP AS A LOADING IN THE ELECTRIC DISCHRGE CIRCUIT AND GIVING ON ITS BASIS THE PARAMETERS OF LOADING

It is supposed that in the circuits of a pulse-arc discharge the power of a high-voltage component of a discharge (during formation of the spark channel) is less in some times than the power of a low-voltage component (during arc discharge). With respect to the circuit specified in fig.1, it can be represented by the expression: $C_2U_2^2/2 < C_1U_1^2/2$, where C_1 and U_1 are the capacity and voltage corresponding to the low-voltage component of the discharge, C_2 and U_2 are the capacity and the voltage corresponding to the high-voltage component of the discharge. Here it is supposed, that at the final stage

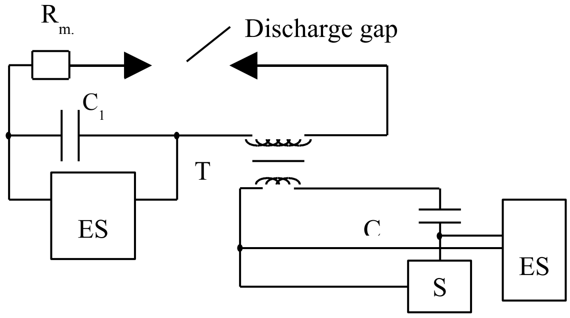

Fig. 1 The circuit of pulse-acr discharge into gas. C_1 and C_2 – electric capacitor, ES - energy supply, S – switch, T – transformer, R – resistor for measure

of development of the spark channel its parameters practically correspond to parameters of the arc discharge.

Taking into account the above-said, it is supposed that to consider a problem of the energy release efficiency is the most important during arc confining. For this purpose it is necessary to estimate the parameters of the arc channel. The latter is possible proceeding from the experimentally known voltage-current characteristics (VCC) of positive columns of gas arcs, as well as from VCC of a vacuum arc with various electrodes [3].

Proceeding from this it is possible to estimate the arc column resistance knowing the distance between electrodes and the value of the average arc confining current. It is necessary also to take into consideration the influence of an envelope and pressure in the discharge cavity on VCC of the discharge gap. By VCC of vacuum arcs one can determine the value of the resistance for a current caused by the processes near the electrodes during the discharge. It should be noted, that the value of the cathode potential drop is changing insignificantly at various values of the arc current and, besides, depends on the cathode material. The value of the anode potential depends of the material and the geometry of the anode. The latter one influences (via the value of the current density) on the form of arc binding to the anode surface resulting in changing the anode potential drop. At discharge duration less than 100 μs the use of VCC of stationary arcs results to the error of conductivity of orders of magnitude, but nevertheless such an approach allows one to calculate conditions for release of a major part of energy of the condenser in the discharge gap.

The set of parameters of loading in this case is reduced to the following. An initial condition of a task is the required energy Q_d that should be released in the discharge channel during the period Δt of a short-term arc confining. It is known, that $Q_{д} = I_c^2 R_a \cdot \Delta t$, where Ic is the average current of arc confining, R_a is the average resistance of the discharge channel during arc confining (i.e. resistance of a positive column of the arc in gas). The instantaneous value of resistance R of the arc channel can be expressed by the function R (I, r), where r is the distance between electrodes, I is the instantaneous value of the arc current. Actually, the function of the instantaneous resistance R of the arc channel should include also the time operator of the discharge t. As at constant values of I and r and of the discharge time $t > t_{eq}$(where t_{eq} is the time of equilibrium condition establishment in the plasma channel) the value of R becomes minimum it is offered to apply in the analysis the function R corresponding to the stationary arcs. From here, the optimization of loading parameters is reduced to the setting of the average arc confining current and distance between electrodes. Then one should observe the condition: $R_{eq} >> R_{el}$, where R_{el} is the resistance of the near-electrode regions at the given value of the average arc confining current.

The chosen value of the distance between electrodes allows one to determine the minimum voltage of arc starting taking into account the thermodynamic condition of gas in the discharge gap and the shape of electrodes. Besides, now it is possible to establish a required value of the voltage of a low-voltage component of the discharge.

3. REQUIREMENTS TO ELEMENTS OF THE ELECTRIC CIRCUIT IN THE CIRCUIT OF A PULSE-ARC DISCHARGE

It is obvious, that for release of a major part of energy in the discharge gap the condition: $R_n >> R_{out}$ should be observed where R_n is the minimal resistance of the arc column of the discharge channel, R_{out} is the resistance of the external electric circuit including the resistance of electrodes at boundary surfaces.

Proceeding from VCC the resistance of the arc channel in the air environment with its length of $3 \cdot 10^{-3}$ m and the current of 100 A is less then $10^{-2}\Omega$. Such a low resistance of the loading results in the specific making of electrical circuit elements. Besides measures undertaken for decreasing the length of the electric circuit and for increasing the cross-section of wires, it is necessary to take into account the increase of an active resistance caused by the phenomena of skin effect and proximity effect (in the pulse transformer) [4].

As a break-down of the discharge gap is characterized by the period of discharge delay, it is necessary to maintain a high voltage at the output of a pulse transformer [5]. To realize such a confining is a difficult task requiring the coordination of loading that practically it is not possible because of the initial high resistance of the discharge gap and the low internal resistance of the primary circuit. Therefore, it is more reasonable to obtain at the output of the pulse transformer a higher voltage of a shorter duration, than it is necessary for the break-down of a discharge gap. In this case the steep front of voltage increase allows one to decrease the energy input for a break-down and to reduce the period of arc starting delay.

One of determining parameters of the discharge is its duration. Its value undergoes the essential influence of inductive resistance of circuit elements. Therefore, to increase the instantaneous power of an energy input into the discharge, it is necessary to apply lead-in wires and capacitors with a low value of internal inductance, and also to supply a low residual inductance of the pulse transformer at the instant of beginning of the period of arc discharge.

4. EXPERIMENTAL PART

In the circuit of a pulse-arc discharge the pulse transformer made by the circuit design (fig.2) was applied. The core transformer was made from electrotechnical steel of mark ЭТ3424 with the complete cross-section of $7.5 \cdot 10^{-4} m^2$.

The secondary winding was 10 turns of a wire of the cross-section 2×6 mm^2. This winding was made as a single layer located near of the core.

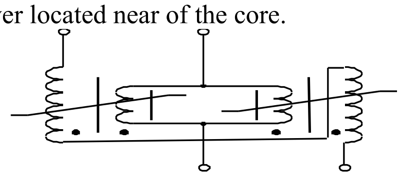

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Fig.2. Schematics of windings into the transformer

The ratio of the wire diameter to the winding step is 1:2. The conversion coefficient was 1:2. The initial inductance of secondary winding magnetization was 76 μH, the leakage inductance was 20 μH, for the primary winding it was 20 μH and 10 μH, respectively. The ТГИ2-400/16 gas triode was applied as a switchboard. The pulse condensers of КВИ-3 mark with a 6×680 nF total capacity were applied in the role of a capacitor store. The pure resistance of a secondary winding of the transformer has made $5{\cdot}10^{-3}$ Ω. The active resistance of the communication circuit was $1.4{\cdot}10^{-2}$ Ω. The condenser of МБГН mark with 200 μF capacitor was used as a low-voltage capacitor store.

When testing the transformer under loading without connection into the discharge circuit of the capacity C_1 the discharge gap of about 3 mm in the air under atmospheric conditions were broken down with stability. In this case the charge voltage in the primary circuit was 13.5 kV. In other case, when the capacity C_1 was initially connected into the discharge circuit, a spark had not been becoming up. When the 6nF capacity was connected into the circuit instead of above one, the stability of a spark was restored. It is believed, that in such a circuit the capacity C_1 together with the parasitic capacity the loadings carried out the function of a capacitor divider that resulted in a significant fall of amplitude of a high-voltage pulse on loading. The completion of the given circuit has allowed us to remove this disadvantage.

The polarity of a charge of capacities was chosen so that the transformer during arc discharge development carried out the function of a switching pulse transformer. The measured characteristic curves of current and voltage development are given in fig.3. The high-voltage jump in the given oscillogramm is not visible, though actually it exists. It is obvious, that the initial steps of the voltage change curve are caused by the induction of the transformer without the full saturation of the magnetic core.

Further the longer step of the voltage fall curve is caused by the internal inductance of the capacity C_1 and by the residual inductance of the transformer winding. It was revealed, that the core pulse transformers in such circuits made from ferrite are more expedient. The requirements to the allowable internal inductance of the condenser are to be determined proceeding from a necessary gas heating rate.

5. CONCLUSIONS

The requirements to elements of an electrical circuit arising on taking into consideration the parameters of loading in the form of a discharge gap are technically achievable in the circuits of the pulse-arc discharge. This circumstance creates an opportunity of application of such a circuit in the plasma-wave system for formation of intensive shock waves, as well as, in other technical devices, where the high-speed electric discharge way of gas heating is required [1].

REFERENCES

1. K.V.Korytchenko, Yu. Ya.Volkolupov et al. // *JTPh*. 2002, v.72, No.4, p.124-125.
2. S.A.Romanenko. *Pulse arches in gases*. M.: Nauka, 1968, p.195.
3. Yu.P.Rayzer. *Gas Discharge Physics*. M.: Nauka, 1987, p.591.
4. S.S.Vdovin. *Designing pulse transformer*. M.: Energiya, 1971, p.147.
5. J.Mik, J.Kreg. *Electric break-down in gas*. M.: Publishing house of the foreign literature, 1960, p.495.

ТРЕБОВАНИЯ К СИСТЕМЕ ЭЛЕКТРИЧЕСКОГО РАЗРЯДА В ПЛАЗМЕННО-ВОЛНОВОЙ СИСТЕМЕ

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Проведен анализ электрической цепи газового разряда. Для анализа предложено рассматривать газоразрядный промежуток в виде нагрузки в соответствующей цепи. Приведены данные по практической реализации такой системы электрического разряда. Динамика энергетического баланса в канале газоразрядного промежутка, характеризуемая выбранной разрядной цепью, подтверждена экспериментально.

ВИМОГИ ДО СИСТЕМИ ЕЛЕКТРИЧНОГО РОЗРЯДУ У ПЛАЗМОВО-ХВИЛЬОВІЙ СИСТЕМІ

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Проведено аналіз електричного кола газового розряду. Для аналізу запропоновано розглядати газорозрядний проміжок у виді навантаження у відповідному колі. Приведено дані з практичної реалізації такої системи електричного розряду. Динаміка енергетичного балансу в каналі газорозрядного проміжку, що характеризується обраним розрядним колом, підтверджена експериментально.