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Analysis Of The Possibility Of Increasing The Efficiency Of The Ozone Electrosynthesis Process

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Abstract. The article provides information about the existing methods of ozone electrosynthesis and identifies their drawbacks. Based on the analysis of processes in the power supply circuit of ozone generators with sinusoidal and pulse voltage of high duty cycle, the possibility of reducing losses and increasing efficiency, increasing the yield of ozone, is substantiated. The distribution of the electric field intensity over the elements of a cylindrical ozone generator was analyzed when it was powered by a sinusoidal and periodic pulse voltage with a duty cycle of more than 5. It was found that it is possible to generate ozone without pre-cooling and drying the air, or cooling the dielectric barrier with running water.

Keywords: Ozone, electrosynthesis, sinusoidal, pulse voltages, dielectric barrier, and amplitude.

Since its discovery at the end of the 18th century, ozone has been of constant interest to specialists and researchers of various profiles due to its unique properties, primarily - its high oxidizing and disinfecting capacity. Ozone (oxidation potential 2.07 V) ranks third among known oxidizing agents, chlorine (1.73 V) is eighth, and oxygen is thirteenth. In industrially developed countries, ozone is widely used in the chemical and petrochemical, metallurgical, electronics, pulp and paper, paint and varnish, microbiological, and food industries, as well as in mechanical engineering, agriculture, medicine, and utilities. It is known that the byproducts formed during the chlorination of water are toxic substances and cannot be completely removed from drinking water. In ozonation, unlike chlorination, oxidation reactions occur, during which non-toxic final compounds are formed. These compounds are easily removed by filtration [1].

Developing a more efficient method of electrosynthesis will increase ozone yield, efficiency, eliminate dielectric barrier heating, and simplify the air preparation process before supplying it to the OG, which will simplify the technological scheme of ozone electrosynthesis and expand the scope of their application.

In addition to the known technological processes using ozone, the use of ozone in greenhouses for disinfecting irrigation water, controlling pests, plant diseases, rotting bacteria and spores, etc., is of interest.

In existing ozone electrosynthesis devices, sinusoidal voltages with a frequency of 500 Hz are used. When the ozone generator is powered by a sinusoidal EMF source, the current i in the circuit has a complex harmonic composition. The averaged curve of the instantaneous value of the current i contains breaks (Fig. 1) at the moments of discharge occurrence. Discharge occurs and stops twice during the period of the supply voltage u.

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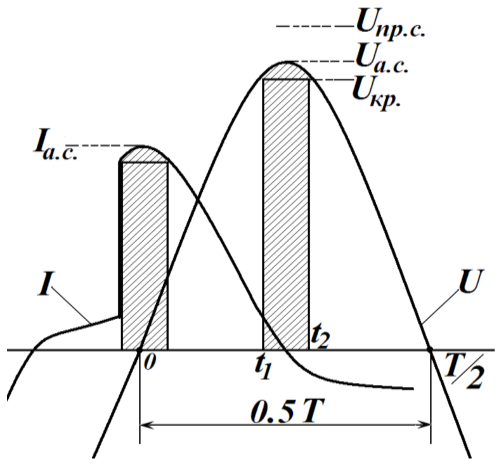

Fig.1. Mediated curves of the instantaneous value of the sinusoidal voltage and current through the ozone generator

The existence of a discharge is possible if the operating voltage Ua.c on the ozonizer exceeds some minimum voltage Uкр. In this case, Ua.s is chosen to be less than the full electrical breakdown voltage of the discharge gap. When powered by sinusoidal voltage, the dielectric barrier heats up, which leads to a decrease in ozone output. Therefore, ozone generators are designed to cool the barrier-covered electrode with running water [1].

Let's analyze the process of ozone electrosynthesis when powered by sinusoidal voltage using the known theory of sinusoidal currents with the substitution of parameters corresponding to the barrier discharge process [2]. The total power supply of the ozone generator (OG) is equal to

$$P_{общ} = \left(\frac{1}{T} \int_0^T u^2 dt \right)^{0.5} \times \left(\frac{1}{T} \int_0^T i^2 dt \right)^{0.5} . \qquad (1)$$

Circuit power during barrier discharge

$$P_{раз} = \left(\frac{1}{T} \int_{t1}^{t2} u^2 dt \right)^{0.5} \times \left(\frac{1}{T} \int_{t1}^{t2} i^2 dt \right)^{0.5} . \qquad (2)$$

In equations (1) and (2)

$$u = U_{a.c} \sin(\omega_c t - 0.5) , \qquad (3)$$

$$i = I_{a.c} \sin \omega_c t , \qquad (4)$$

where ωs is the angular frequency of the sinusoidal voltage;
u, i - instantaneous values of current and voltage;
Ua.s.- amplitude of sinusoidal stress;
Ia.c. - discharge current amplitude;
T - period of sinusoidal stress;
t1 - discharge start time;
t2 - discharge completion time;
Loss power is equal to

$$P_{пот} = P_{общ} - P_{пот} . \qquad (5)$$

From the analysis of formulas (1...5), it follows that a significant power loss occurs during the time when there is no discharge in the FM. Hence, the working hypothesis follows: the efficiency of the ozone electrosynthesis process can be increased by using periodic voltage pulses that have a shape similar to the shaded area of sinusoidal voltage, i.e., a rectangular area with a large wellbore (Figure 2). In this case, it is possible to increase the amplitude of the supply voltage Ui.a above the breakthrough threshold of the sinusoidal voltage Upr.s, which is characterized by the overvoltage coefficient [3,4].

$$K = U_{i.a} / U_{pr.s}. \tag{6}$$

In an impulse power supply, the GO capacitor is charged to the amplitude value of the voltage, which is higher than the amplitude of the sinusoidal voltage. In the time interval 0 - t1 (Fig. 2), the discharge power is determined by the dependence

$$P_{0-t1} = I_{a.u} \cdot U_{a.u}. \tag{7}$$

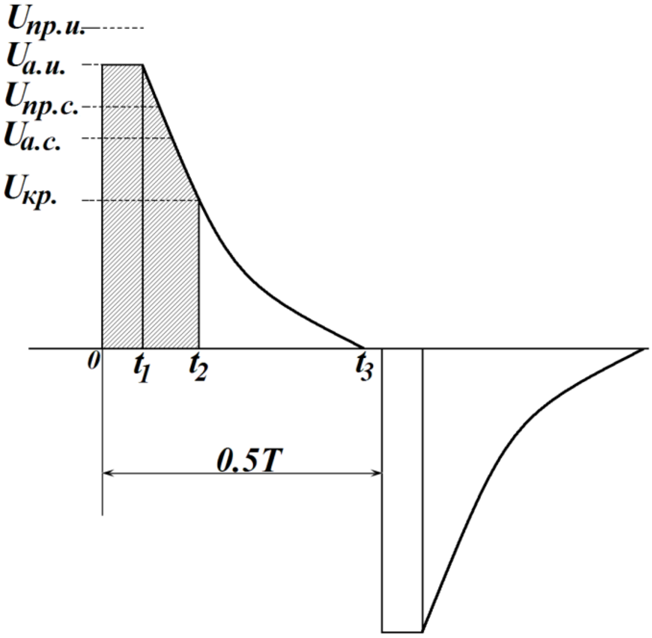

Fig.2. The process of changing the voltage in the discharge gap when powered by periodic voltage pulses

In the pause between the pulses (time from t1 to t2), the discharge power will be determined by the charge stored in the GOs. The charge will be discharged at the loss resistance Rpot of the transformer, the resistance Robm, and the inductance L of the secondary winding of the step-up transformer, which are elements of the oscillatory circuit (Fig. 3). In this case, due to the fact that R/2L< (CL) 0.5 [2], we have a small attenuation in the circuit, which is the sum of the loss currents at Rpot (the first term of the right side of the equation) and the process in the circuit $R_{obm}\,LC_{go}$:

$$P_{t1-t2} = \frac{U^2_{a.u}}{R_{пот}} e^{-\frac{2t}{R_{пот}C_{ГО}}} + \frac{U^2_{a.u}}{R_{обм}} e^{-\frac{tR_{обм}}{2L}} \left(\cos\omega_{к.к} t + \frac{R_{обм}}{2\omega_{к.к}} \sin\omega_{к.к} t \right). \tag{8}$$

In formula (8) the angular frequency ωk.k of the oscillatory circuit is determined by the relation

$$\omega_{к.к} = \left(\frac{R^2{}_{обм}}{4L^2} - \frac{1}{LC_{ГО}} \right)^{0.5}. \tag{9}$$

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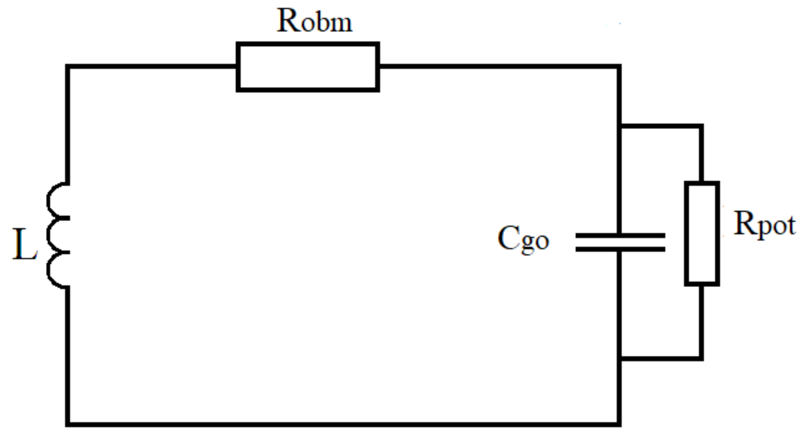

Fig.3. Diagram of replacement of the power supply circuit of the ozone generator discharge gap during the pause between pulses

Starting from the time t2, the discharge voltage decreases below the critical Ucr, the discharge stops, and the capacitor is discharged by Rобм, which constitutes the loss power.

$$P_{t2-t3} = \frac{U_{a.u}^2}{R_{обм}} e^{-\frac{tR_{обм}}{2L}} \left(\cos \omega_{к.к} t + \frac{R_{обм}}{2\omega_{к.к}} \sin \omega_{к.к} t \right). \qquad (10)$$

Analysis of equations (7-10) shows that the main part of the energy of periodic voltage pulses is spent on the discharge process, which is accompanied by the electrosynthesis of ozone.

In high-voltage ozone generator power supply circuits, the active resistance of the secondary winding of the step-up transformer can range from 2 to 20 kΩ, the inductance from 50 to 200 H, and the capacitance of ozone generators from 10-7 to 10-9 F. In this case, the condition (Rобм/2L) < (LC) is met, and the discharge occurs in the circuit with a small attenuation. To transition the circuit to critical attenuation mode, a capacitor with a capacitance exceeding the capacitor's capacitance can be connected in parallel to the OG, which will increase the frequency of periodic voltage pulses and, accordingly, the energy indicators of the ozone electrosynthesis process.

In existing ozone generation devices, the barrier effect is used. It consists in the fact that the ozonizer has a dielectric layer, or as it is often called, a barrier, which stabilizes the discharge current and gives the discharge a uniform character [1]. We believe that this statement is not entirely justified; according to a number of authors, during electrical independent discharges in gases, the processes of charging, recombination, and transfer of volumetric charges occur simultaneously, while the amplitude and frequency of discharge currents are random quantities and vary within large limits [3, 4], hence the barrier's stabilization ability is questionable.

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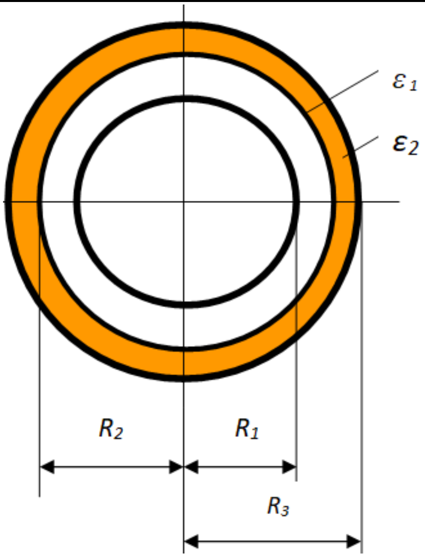

Figure 4. Parameters of the cylindrical ozone generator: ε1 - relative dielectric permittivity of the gas discharge gap; ε2 - relative dielectric permittivity of the dielectric barrier; R1 - external radius of the internal electrode; R2 - internal radius of the dielectric barrier; R3 - internal radius of the external electrode

The presence of a dielectric barrier causes the ozonator to be supplied with alternating electric current. Glass is usually used as a dielectric in the production of ozonizers. According to the number of dielectric barriers, ozonizers can be divided into two types: some have two dielectric barriers (solid glass), in which discharge occurs between two dielectrics; other ozonizers have one dielectric barrier [1,5].

By the shape of the electrodes, tubular and plate ozonizers are distinguished. For the operation of ozonizers, this difference is not fundamental, although in the latter case, it is more difficult to avoid some extreme effects.

Tubular ozonizers, consisting of a set of tubular electrodes placed in a common cylindrical housing, are most widely used. The tubular ozonator is a two-layer capacitor in which the electric field is created between two cylindrical surfaces with a common axis (Fig. 4) and has a radial direction. Due to symmetry, equipotential surfaces have a cylindrical shape; the axes of these surfaces coincide with the common axis of the electrodes, and in all points of the same equipotential surface, the magnitude of the electric field strength is constant and decreases from one equipotential surface to another.

To determine the capacitance of such a capacitor and the electric field strength in each dielectric, let's imagine that along the interface between two dielectrics, we placed an infinitely thin metal cylinder [2]. Such a metal cylinder does not distort the electric field in each dielectric, since the interface remains equipotential (any conducting surface in the electric field is equipotential).

In this case, the gas gap capacitance will be equal to:

$$C_1 = 2\pi\ell\varepsilon_0\varepsilon_1(\ln R_2 / R_1), \qquad (11)$$

where l - length of the capacitor, m;

ε0 = 8.85•10-12 F/m - electric constant.

Dielectric barrier capacitance

$$C_2 = 2\pi\ell\varepsilon_0\varepsilon_2(\ln R_3 / R_2), \qquad (12)$$

Capacitance of series-connected capacitors

$$C = C_1 C_2 / (C_1 + C_2) \qquad (13)$$

Electric field strength of a cylindrical capacitor

$$E = Q / \varepsilon_0 \varepsilon 2\pi R\ell, \qquad (14)$$

where R is the radius of the equipotential surface for which the electric field strength is determined.

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Since when capacitors are connected in series, the charges on all plates are the same in magnitude, then

$$Q = C_1U_1 = C_2U_2 = CU \qquad (15)$$

From this, it is possible to determine the electric field strength in each layer of the capacitor. Electric field strength in the gas layer

$$E_1 = CU / \varepsilon_0\varepsilon_1 2\pi R_{\varepsilon 1}\ell, \qquad (16)$$

where $R_{\varepsilon 1}$ is the radius of the equipotential surface in the gas layer for which the electric field strength is determined.

Electric field strength in the barrier layer

$$E_2 = CU / \varepsilon_0\varepsilon_2 2\pi R_{\varepsilon 2}\ell, \qquad (17)$$

where $R_{\varepsilon 2}$ is the radius of the equipotential surface in the barrier layer for which the electric field strength is determined.

For numerical analysis, we use an ozone generator with parameters: R1=0.011m; R2 = 0.017 m; R3=0.02 m; ε1=1; ε2=7. The parameters of the sinusoidal and impulse voltages are presented in Table 1.

Table 1. Parameters of sinusoidal and impulse voltages used in experimental studies

Parameters	Sinusoidal 50 Hz	Impulse 100 Hz
Effective voltage, kV	9,4	4,12
Voltage amplitude, kV	13,5	20,6
Discharge current, mA	1,5	6,8
Amplitude coefficient	1,41	5

Table 2. Results of calculations of the influence of the dielectric barrier parameters on the electrical parameters of the ozone generator

№	Determinedparameter	Designation	Used formula	Parameter value
1.	CO gas layer capacity, 10^{-11} F	C_1	(11)	5.1
2.	Dielectric layer capacitance,10^{-10} F	C_2	(12)	9.57
3.	Total capacity of FG with barrier,10^{-11} F	C	(13)	5.03
4.	Radius of the equipotential surface in the gas layer, m	$R_{\varepsilon 1}$	$(R_1+R_2)/2$	0.014
5.	Equipotential barrier surface radius, m	$R_{\varepsilon 2}$	$(R_3+R_2)/2$	0.0185
6.	Equipotential surface radius of a barrierless capacitor, m	$R_{бб}$	$(R_3+R_1)/2$	0.0155
7.	Electric field strength in the gas layer, kV/m	E_1	(16)	873* 1332**
8.	Electric field strength in the barrier, kV/m	E_2	(17)	94* 144**

Note: * - parameters for sinusoidal stress;
** - parameters for impulse voltage

Amplitude values of sinusoidal and impulse stresses were used in the calculations. This is due to the fact that discharge processes occur in a narrow section of stresses adjacent to their amplitudes. The calculation results are presented in Table 2, the analysis of which shows that the presence of a dielectric barrier significantly increases the electric field strength in the gas layer, which contributes to the process of ozone electrosynthesis.

Conclusion

The use of large-scale pulse voltages will eliminate such shortcomings of existing ozone generators as the need to heat and cool the dielectric barrier, increase their operational reliability, and increase ozone yield.

When powering the discharge gaps of the DC system with periodic pulses, power losses are significantly reduced compared to the sinusoidal voltage. Ozone yield increases due to exceeding the

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impulse voltage amplitude. An essential condition for the efficient operation of the discharge system is the necessity of fully discharging the discharge gap capacitance, which eliminates the process of capacitance recharging accompanied by energy losses and barrier heating.

References

1. Filippov Yu.V., Boblikov V.A., Panteleev V.I. Ozone Electrosynthesis.- Moscow: Moscow University Publishing House, 1987. - 237 p.

2. Demerchan K.S., Neumann A.R., Korovkin N.V., Chepuria V.P. Theoretical Foundations of Electrical Engineering. Volume 2. - Moscow: Higher School, 2006.-575 p.

Korolev Yu.D., Mesyas G.A. Physics of Pulsed Gas Breakthrough. - Moscow: Nauka. Main Editorial Office of Physical and Mathematical Literature, 1991. - 224 p.

4. High Voltage Technique/ Edited by M.V. Kostenko. - Moscow: Energy, Textbook for Universities. 1993.-528p.

5. Lunin V. V., Popovich M. P., Tkachenko S. N. Physical Chemistry of Ozone. Moscow: Moscow University Publishing House, 1998. - 215 p.