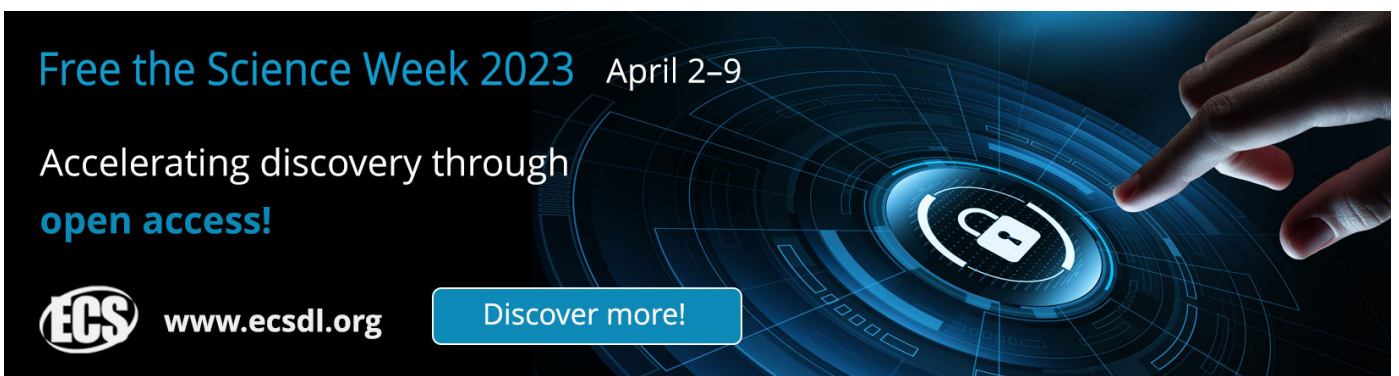# Analysis of the double-side power supply for electronic-ion technology devices with pulse voltage

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Analysis of the double-side power supply for electronic-ion technology devices with pulse voltage

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Abstract. This article provides an analysis of existing high voltage power supply devices for devices of electron-ion technology, in particular devices for cleaning gases from aerosol particles. Advances in this technology are described. The following are the disadvantages of the electric fields of a corona discharge when powered by a constant high voltage. To increase the efficiency of catching aerosol particles, the authors propose to combine self-sustained and non-sustained discharges in one discharge gap. To do this, it is proposed to use unipolar high-voltage pulses with a constant component and pulses with a duty cycle of more than 5. An analysis is made of the possibility of increasing the efficiency of the impact of electric fields when using circuits with two-sided power supply, the analysis of which makes it possible to increase the pulse repetition rate, as well as to regulate the process of the impact of electric fields on processed particles., regulation by the parameter of impulse voltage.

1. Introduction

Scientific and technological progress has ensured an unprecedented increase in human power in relation to nature. Thanks to this, man is able to move mountains, turn rivers, create new seas, turn vast deserts into fertile oases. Man's production-economic and scientific-technical activity has reached cosmic proportions.

Any pollution causes a protective reaction in nature, aimed at its neutralization. This great ability of nature has long been exploited by man thoughtlessly and predatory. From century to century, the practice of widespread use of the self-purifying ability of the atmosphere has evolved. Production waste was thrown into the air in the expectation that all of them would eventually be neutralized and recycled by nature itself [1]. At the same time, there was no thought about the damage caused to her. It seemed that no matter how large the total mass of waste, they are insignificant compared to protective resources. However, with the progressive growth of pollution, it becomes obvious that natural self-purification systems will sooner or later not be able to withstand such an onslaught [2, 3]. In this regard, large volumes of harmful emissions into the atmosphere cause a number of adverse global and regional phenomena. Global phenomena include acid rain, ozone layer destruction, the greenhouse effect, etc. Regional phenomena are observed in places where harmful substances are emitted and have a negative impact on the population, plants and animals [4, 5].

Various methods and devices are used to clean the gases and air of industrial premises exhausted in technological processes, of which the most preferable are electrostatic precipitators, the distinguishing ability of which is high cleaning ability, high productivity of the purified gas, trapping aerosol

particles smaller than 0.1 μm with any physical properties. -mechanical properties, no aerodynamic drag.

The development of electrical gas cleaning technology falls on the period of 50-80 years of the last century [6-10]. In 1949, on the basis of the Central Research Laboratory NILOGAZ, the State Research Institute for Industrial and Sanitary Gas Purification - NIIOGAZ was established. The creation of the institute marked a milestone in the development of domestic science in the field of gas cleaning, contributed to the opening of broad prospects for a deeper approach to solving the most important problems of gas cleaning and dust collection.

Highly efficient devices providing a high degree of purification have been studied by the authors [11-17]. The scope of electrostatic precipitators has been significantly expanded. The production of unified electrostatic precipitators has been launched, the size range of which includes high-performance devices that clean the flue gases of boilers of large power units of 300, 500 and 800 MW, large cement production kilns and other technological devices.

Since the beginning of the 80s of the 20th century, the main work on electrogas cleaning is mainly associated with an increase in the efficiency and reliability of already developed electrostatic precipitators. Power units for electric filters of the ATP type have been developed. Thanks to the use of thyristor control, silicon rectifiers and other semiconductor devices, the reliability of the units has significantly increased. The developed principles of voltage regulation made it possible to maintain an increased load on the electrodes of electrostatic precipitators, which provide a high degree of purification [6].

2. Methods

Noting the great achievements in the technology of electrical gas purification, we will analyze the reasons that prevent the wider use of electrostatic precipitators in the purification of exhaust gases in technological processes, as well as their use for air purification from solid and liquid aerosol particles in industrial, public, medical and residential premises.

Here, first of all, it should be noted the significant dimensions and weight of the electrostatic precipitators with high power consumption. The dimensions of the electrostatic precipitators of the UGZ series range from 18.6x12x15.4 m to 24.8x21.8x27 m, while the zone of deposition of aerosol particles $A1 = 15.4 ... 27$ m. Power supplies up to 200 kVA are used to power the electrostatic precipitators. The flow rate of the purified gas is $V1 = 1...1.5$ m/s. If the sedimentation zone is reduced to $A2$, and the gas flow rate is increased to $V2$, then the power consumption of electrostatic precipitators at the same performance will decrease by $[(V1/V2) \cdot (A1/A2)]$ times. In proportion to the power, the dimensions of the electrostatic precipitators will also decrease.

This goal can be achieved with a significant increase in the efficiency of gas purification in electric fields. The main determining factors of this process are the magnitude of the charge on the trapped particles Q and the electric field strength between the electrodes of the electrostatic precipitator E or the Coulomb force ($Fk = QE$). Known methods for improving the efficiency of electrostatic precipitators, using pre-charging, do not give the desired result. This conclusion is based on the results of our experimental studies of the dynamics of the force action of uniform electric fields on material particles. These studies were carried out with particles precharged in a corona discharge field and charged with water aerosol. The interaction of the preliminary charge with the electric field manifests itself in the form of a short-term force pulse with a duration of about 0.05 s, after which the usual process of contact charging of the particle occurs according to the exponential law. In this case, the largest force impulse was observed when charging with a water aerosol. When pre-charging in the corona discharge field, the force impulse is 2...3 times less.

3. Results

Of scientific and practical interest is the combination in one technological gap with one power source of independent and non-self-sustained discharges. This can be achieved, for example, by using a high-

duty unipolar pulsed voltage with a constant component below the self-discharge threshold. The impulse voltage in this case should be characterized by the following parameters (Figure 1):
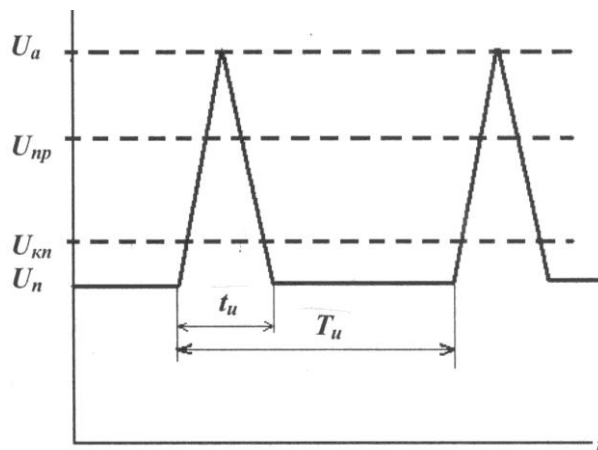

Figure 1. Parameters of high-voltage unipolar pulses for combining self-sustained and non-sustained discharges in one discharge gap

• voltage pulse amplitude - Ua, V;

• constant component of the voltage impulse – Up, V;

• effective value of voltage - Ud,, V;

• pulse duration - τi, s;

• pulse repetition period – Ti, s;

• pulse duty cycle - $K = T_i / \tau_i$;
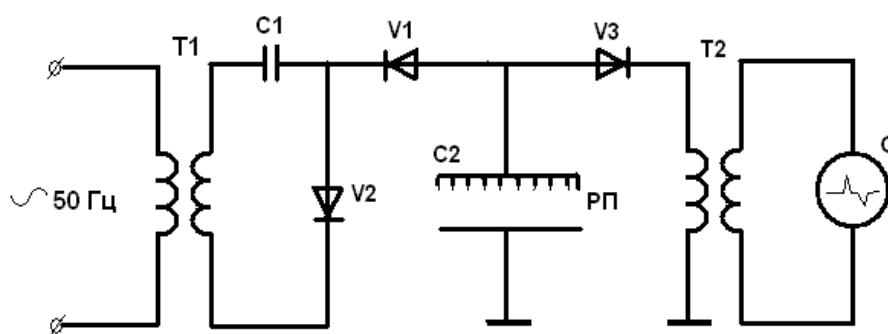
• pulse frequency -n,s^{-1}.

Figure 2. Schematic diagram of the generation of high voltage unipolar pulses with two-sided power supply

The use of high-duty unipolar voltage pulses makes it possible to significantly increase the efficiency of the impact of electric fields on particles of processed materials. For example, when using such voltages in the processes of electrogas cleaning, it is possible to increase the speed of the cleaned gases up to 10 m/s, reduce the zone of aerosol particles deposition to 1 m, and the mass of internal equipment to 0.3 tons. These parameters for electrostatic precipitators of the UG2-4-74 type, which

are powered by sinusoidal voltage rectifiers, are 1 m/s, 27 m, 172 tons, respectively. In this case, the power consumption can be reduced by more than 100 times and the efficiency of gas purification from dust particles is significantly increased. In these studies, acute-angled periodic impulse voltages with a crest factor of more than 5 were used, after rectification at one stage of the voltage multiplication circuit. The efficiency of various technological processes can be significantly increased by using a two-way supply rectifier circuit (Figure 2).
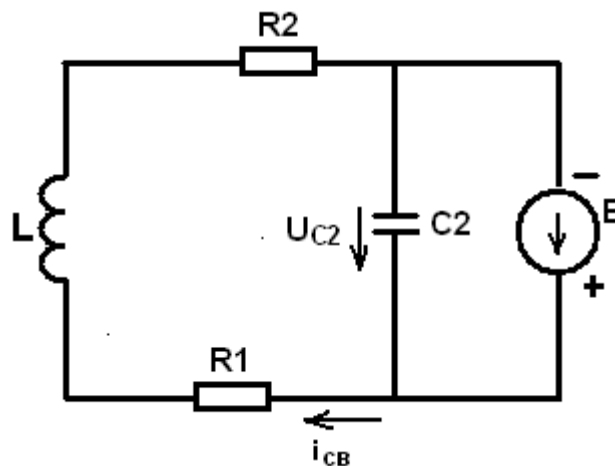

Figure 3. Equivalent circuit of a high-voltage pulse source with two-sided power supply in the pause between pulses

In the circuit, to create a constant component of the impulse voltage, a step-up transformer T1 is used, with the help of which the mains voltage is increased. The increased mains voltage is rectified by a voltage multiplication circuit (C1, V1 and V2) and is fed to the discharge gap of the RP (C2). The pulsed periodic voltage, after increasing on the transformer T2, is rectified by the valve V3 and superimposed on the constant component.

As for the previous scheme, we determine the law of change in the voltage and current of the discharge gap in the pause between pulses. To do this, we compose the characteristic equation of the circuit in complex form according to the equivalent circuit (Figure 3)

$$Z=R_1+R_2+j\omega L+1/j\omega C_2. \tag{1}$$

Let us replace the factor $j\omega$ by p and equate the resulting expression $Z(p)$ to zero:

$$Z(p)=R_1+R_2+pL+1/pC_2,$$

or

$$p2(C2L)+pC2(R1+R2)+1=0. \tag{2}$$

The roots of the characteristic equation (1) are determined by the equality:

$$p1,2 = \{-C2\ (R1+R2) \pm[(\ C2\ (R1+R2))2-4(C2L)]0.5\}/2C2L). \tag{3}$$

Hence the free component of the voltage of the discharge gap:

$$U_{C2} = (A1er1t + A2er2t)+U_0, \tag{4}$$

and the current in the circuit

$$ic \u003d C2 (A1p1er1t + A2p2er2t). \tag{5}$$

From the initial conditions: $UC2,a=2U0$; $iw,0 = ia$, we get

$$Ua=A1+A2 ; ia = A1p1 + A2p2. \tag{6}$$

From here

$$A1 = (p2Aa -ia)/(p2 - p1), \tag{7}$$
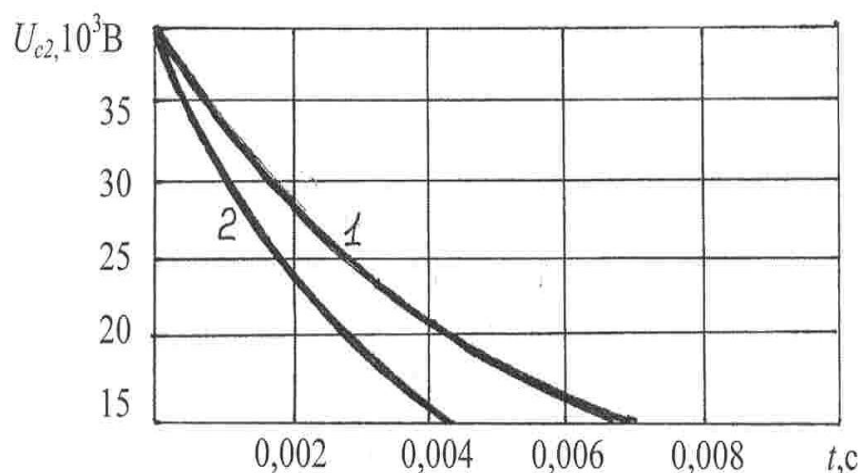
$$A2 \u003d (p1Aa - ia) / (p2 - p1). \tag{8}$$

Figure 4. The process of changing the voltage of the discharge gap in the pause between pulses for a rectification circuit with voltage multiplication (1) and for a circuit with two-sided power supply (2)

With these values of the integration constants, the voltage of the discharge gap and the circuit current and the circuit current in the pause between pulses will change according to the law:

$$U_{C2} = \{1/ (p2-p1)[(p2Ua-ia)ep1t-(p1Ua-iat)ep2t]+U0 , \tag{9}$$

$$i_c = C2/ (p2-p1)[(p2Ua-ia)p1ep1t-(p1Ua-iat)p2ep2t]. \tag{10}$$

To compare two power supply circuits for the discharge gaps of electrostatic precipitators, equations (7) from [8] and (14) were solved on a PC for the following values of the circuit parameters: L=100 H; R1 \u003d 35x103 Ohm; R2 \u003d 2x106 Ohm; C1=10-8 F; C2=10-10 F. Integration step 0.0001s. Due to the same nature of the change in voltage and current, calculations were made only for voltage. The calculation results are presented in the form of a graph in Figure 4.

With the same parameters of the circuit elements for a rectification circuit with voltage multiplication, the maximum frequency at which a stable process of the streamer form of a corona discharge is ensured should not exceed 140 s-1, and for a circuit with two-sided power supply - 232 s-1.

The two-way power supply circuit makes it possible to regulate the constant component of the pulsed voltage within the required limits. In addition, when using a full-wave rectification circuit, to obtain

twice the pulse frequency in relation to the frequency of periodic voltage pulses. The disadvantage of this scheme is the need for two isolated high voltage sources.

The results of the performed analysis are adequate to the results of a series of experimental studies to study the characteristics of the streamer form of a corona discharge.

4. Conclusions

The electric fields of a DC corona discharge used in electrostatic precipitators are brought to the limit of their capabilities and have a number of significant drawbacks: fluctuations in a wide range of amplitude and frequency of the discharge current; locking the discharge; reverse crown; transition to a spark or arc form.

It is possible to stabilize discharge processes in technological discharge gaps by combining the action of self-sustained and non-sustained discharges. A self-sustained discharge in the form of a streamer form of a corona discharge is formed in the discharge gap when exposed to a voltage pulse with an overvoltage, and a non-self-sustained discharge is formed under the action of a constant component of the pulsed voltage, the value of which is below the ignition threshold of a self-sustained discharge.

The frequency of the pulsed voltage is determined by the time of full compensation of the space charges of the gap formed under the action of the voltage pulse, the parameters of the elements of the power supply circuit and the capacitance of the discharge gap.

When powered by high-voltage unipolar pulses with overvoltage, technological discharge gaps can be considered as an element of an electrical circuit.

If during a corona discharge of a constant voltage, the discharge current is a function of a discrete random process, then when powered by unipolar high voltage pulses, the discharge currents are stable in frequency and amplitude

In double-ended circuits, the frequency of the pulses can be increased compared to rectifier circuits with voltage multiplication. In addition, the processes can be controlled by regulating the parameters of the impulse voltage.

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