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Features of Streamer Form of Corona Discharge in respect to Electric Gas Purification

Erkinov Bakhodir, Tolipov Jamshid, NazarovOybek, ChullievYakubjon

Senior Lecturer of Tashkent Institute of Irrigation and Agricultural Mechanization Engineers,
Senior Researcher, Scientific and Technical Center of Uzbekenergo
JSC, Assistant Professor of Tashkent Institute of Irrigation and Agricultural Mechanization Engineers,
Assistant Professor of Tashkent Institute of Irrigation and Agricultural Mechanization Engineers

ABSTRACT:An article briefly describes advantages of streamer form of corona discharge over corona discharge of direct voltage. With the purpose of confirmation of hypotheses about possibility of stabilization of discharge processes in electric fields of streamer form of corona discharge oscillography voltage and current were done, and volt amperage features at various frequencies of impulse voltage were taken. Impact of parameters of electrodes system «Potential plane with corona needles – grounded plane» to value of discharge current was studied. Outcomes of study of power features and character of change in strength of electric fields of streamer form of corona discharge are presented.

KEY WORDS: Stabilization of Current Discharge, Streamer form of Corona Discharge, Electrode System, Impulse Voltage, Coulomb power, Discharge particles.

I. INTRODUCTION

It is impossible to enhance efficiency of gases purification from solid and liquid aerosol particles in the electric fields of corona discharge of direct voltage used in existing electric separators. This is due to the fact that the process of purification depends on value of strength of electric field which is supported in electric separators in pre-disruptive values. Accordingly, further enhancement of strength of field leads to spark or arc breakdown of discharge technological gap.

Enhancement of efficiency processes of electric gas purification is possible at use of streamer form of corona discharge. This type of partial electric discharge in gases incurs in sharply uneven electric fields at impact of impulse voltage with steepedge and overvoltage, i.e. when range of impulse voltage is higher than disruptive threshold of direct voltage [1,2].

However, channel of streamer is electrically neutral and accordingly has an equal number of negative and positiveions. For process of gases purification, a flow of unipolar bulk charges is required. Therefore, for use of streamer form of corona discharge division of bulk charges is required. For getting flow of unipolarbulkcharges a separation of direct electric field in technological discharge gap is required, and for amplification of this field's action the electrodes system «potential plane with corona needles – grounded plane» might be used.
As our study has shown, streamer form of corona discharge has the following advantages in comparison with corona discharge of direct voltage:

- stability of discharge current;
- possibility of analysis of transfer processes in feed circuit impulse of high voltage andconsider the technological discharge gap as an element of this;
- higher efficiency of aerosol sedimentation, particles from the flow of gases;
- possibility of enhancement of purified gases' velocity up to 8 m/s;
- reduction of aerosol sedimentation area, particles up to 0,5…1,0 m;
- substantial reduction of capacity process of electric gas purification;

simplification of principle of automatic adjustment of voltage discharge gap of electric separators on value of discharge current;

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- in view of reduction of parameters electric of separators there is a possibility of process of continuous use of settleddust.

For justification of parameters process of electric gas purification in electric fields of streamer form of corona discharge a number of pilot studies of its features were conducted. Outcomes of these studies are presented in this article.

II. SIGNIFICANCE OF THE SYSTEM

Study was conducted with purpose of confirmation of hypotheses about possibility of stabilization of discharge processes in electric fields of streamer form of corona discharge. Based on this oscillography of voltage and current was made and volt amperage features at various frequencies of impulse voltage were taken.

III. LITERATURE SURVEY

Power of various physical character impacts on aerosol particles in electric fields of corona discharge [1,2,3].Those include: power Coulomb, i.e. interacting charge in particles with electric field; pandero motor force stipulated byirregularity of electric fields; mirror reflection force effecting the settled particles; gravity of particles; force interacting between charged particles of aerosol; force stipulated by gas flow [4];retarding effort to air flow; force stipulated by electric wind. From listed above, coulomb power is the identifying one at aerosol particles sedimentation. Remaining powers are much moreless, and are not considered in practical calculations.
Coulomb power for similar electric fields at feeding by direct voltage is identified by asimple dependence:

$$F_к = Q\,E,$$

Where Q – excess charge of aerosol particles; E – strength of electric fields.

In sharplyuneven electric fields strength of electric fields is greatest in areas directly adjoining to corona-forming electrodes. Therefore, Coulomb power will depend on location of particles in inter electrode space, i.e. from its coordinates:

$$F_к = Q\,qradE.$$

In sharply uneven electric fields at feeding by unipolar impulse of voltage, strength of electric fields will bealsochangedintime. Therefore, Coulomb power will be identified by dependence:

$$F_к = Q\,qradE(t).$$

Strength of electric fields in electric fields of streamer form of corona discharge is changed by law:

$$E(t) = U_{C2.NAT}/H = \{[1/(p_2-p_1)]\ [(p_2U_a-i_a)p_1 expp_1\,t - (p_1U_a-i_a)p_2\, expp_2t] + U_a,^t] + U_a\}/\,H,$$

where $U_{C2.NAT}$ – voltage discharge gap in interval between impulses; H - distance between electrodes;U_a -range of impulse voltage; p_2,p_1 - roofs of characteristic equation.

$$p_{1,2} = \{-C_1\,C_2\,R \pm [(C_1C_2R)^2 - 4(C_1C_2L)(C_1+C_2)]^{0,5}\}/(2C_1\,C_2L),$$

where C_1, R, L, - parameters of circuitry of feed of discharge gap by unipolar impulse of voltage; C_2 – size of discharge gap.
Hence it is seen that in electric fields of streamer form of corona discharge a Coulomb power is identified by parameters of elements of feed source, i.e. dynamic mode of process is obvious, unlike electric fields of corona discharge of direct voltage where such dependence practically does not exist.

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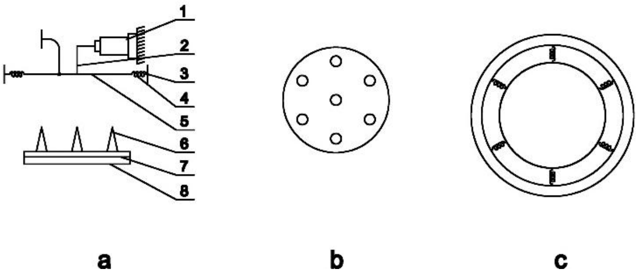

Fig.1. Diagram stand for study of character of change of strength of electric fields in discharge gap at feeding by impulse voltage
(a), layout of corona needles (б), circuitry of suspension of grounded plane (в): 1 – mechanotron; 2 – rigid link; 3 – dielectric ring; 4 -springs of suspension; 5 – grounded electrode; 6 –corona needle; 7 –dielectric disk; 8 –screen electrode

IV. METHODOLOGY

Study conducted under the following methodology (Fig.3). From fluoroplastic of 0,15 mm thickness ring 2 of 20 mm diameter was cut and was placed in the centre of grounded plane 3 under corona needle 1. To the edge of ring a capronic string 6 was fixed which by the other end was fixed to spring dynamometer 6. Dynamometer by string 6 was fixed to drum of micro motor with gear 5. Inter electrode distance was adjusted by clamp 7. Inter electrode distance was 40 mm. To corona needle a voltage $2{,}4x10^4$ V was supplied. In experiment for elimination of impact of power of Coulomb, i.e. interaction of charge particles with external electric field, trial body was charged from corona needle electrode, and then corona-forming electrode with high-voltage switch was grounded and at the same time motor was switched on. Power of mirror reflection was identified in dynamometer during separation of fluoroplastic ring from grounded plane.

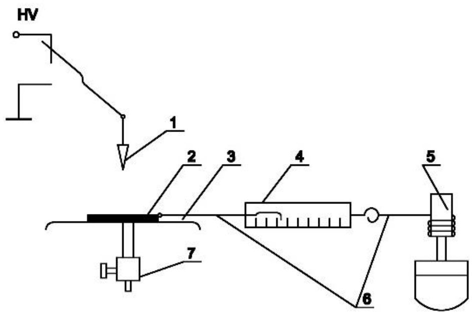

Fig. 14. Diagram stand for measurement of power of adhesion of trial body to grounded plane:
1 - corona needle; 2 – trial body; 3 – grounded plane; 4 – dynamometer; 5 – drum of motor with gear; 6 – capronic string

Value of charge in coulomb fluoroplastic ring was calculated by formula:

$$Q= (2Fr^2)^{0,5},$$

where F – power of separation of ring from grounded plane, H; r – thickness of fluoroplastic, m.

Specific surface density of charges in coulomb /m is identified by formula:

$$\sigma_S = Q/S,$$

where S –fluoroplastic ring area is 1256 mm^2

Experiment was conducted in triple replication. In experiment for elimination of impact of power of Coulomb (interacting charge of trial body with external electric field), trial body first was charged from corona needle electrode, then corona needle with high-voltage switch was grounded, and measurement of power of adhesion of trial body to grounded plane was done.

Table. Outcomes of comparative study of powers of adhesion of trial body to grounded plane in electric fields

Parameters	Value of parameters					
Frequency of impulse, imp^{-1}	65	70	122	154	200	210
F, H	$F_{=}$ 0,62	F_1 1,11	F_2 c 1,21	F_3 1,37	F_3 1.63	F_3 1,44
Q, 10^{-4} Coulomb	0,74	1,0	1,0	1,1	1,2	1,14
σ_S, 10^{-4} Coulomb /mm^2	9,48	12,6	13,2	14,1	15,3	14,4
F_n/F	1,79	1,94	2,21	2,63	2,31	1,79

Pilot study was conducted on stand (Fig.3) where periodic impulse of voltage was generated by machine generator **G** with2 pairs of explicitly expressed poles on rotor and stator. Gearing of generator was made from motor of direct current M. For smooth adjustment of frequency of generator in wide span, adjustment of number of motor rotations was done by change in voltage with autotransformer T1 and rectifier V1. Voltage of generator excitation was adjusted by rheostat R1. Voltage from generator was enhanced by transformer T2. Secondary winding of transformer T2 was done with central grounded point which allowed at use of bilateral circuitry of rectification with multiplication of voltage to get at exit of circuitry the doubled frequency of unipolar impulse of high voltage. Thus, at velocity of motor rotation 50 r^{-1}, frequency at exit of generator was 100 Hz, frequency at exit of circuitry of rectification – 200 imp^{-1}. Circuitry of rectification consists of condensers C1, C2 and high-voltage diodes V2, V3, V4, V5. Voltage was measured with electrostatic kilovoltmeter type C-100 – PV. Current was measured with micro ammeter PA type M-63. Circuit measurement of current was protectedfrom spark discharges by arrester FV.Oscillography of voltage was done through Ohm divider of voltage R2, R3, R4. Oscillography of current – withconductingbridge R5, R6.
Main indicator, characterizing discharge processes, is volt amperage features (VAF). Traditional method of taking of VAF - method of ammeter and voltmeter, has some shortages. Accuracy of measurements depends on the class of accuracy of measuring and adjusting equipment, qualification of the operator. Therefore, for taking of VAF the following methodologywas developed.

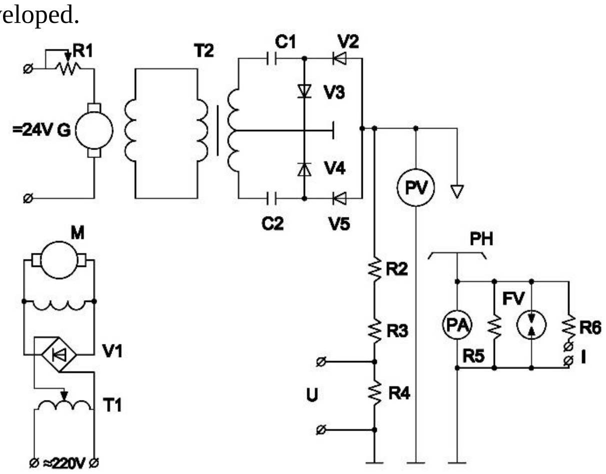

Fig. 3. Schematic diagram of stand for study of features of streamer form of corona discharge: R1...R6 – resistors; G – generator of periodic voltage impulse; V1...V6 – diodes; C1, C2 – condensers; PV –kilovoltmeter; PA –microammeter; FV – arrester; M – motor of gear of generator; T1 –autotransformer; T2 –step-up transformer; U, I –connecting terminals for oscillograph

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Recording of VAF was done on self-recording potentiometerPmV type KSP, calibratedon the discharge current (Fig.3). High voltage supplied to corona needle 8, evenly enhanced by autotransformer 6, assembled on square magneticconductor. Voltage was taken from autotransformer by pickup 3, which moved along spiral shaft 4. Gearing of shaft was done from reactive synchronous motor with gear 1 type SD-4. Automatic control of stand was done with arresters 2 and 5. Voltage from autotransformer was supplied to source of high voltage 7 and after enhancement and rectification to corona needle 8.

Calibration of VAF for voltage was done by formula:

$$U = U_{MAX}/(Vt), \ (10^3 V/mm)$$

where U_{max}-peak voltage supplied toto stand, 10^3V; *V*-velocityof conveyer belt, mm^{-1}; *t* -full time of recording VAF, s. VAF were taken for frequencies span of 10…220 imp^{-1}. For checking, VAF corona discharge at feeding of source of high voltage with voltage of industrial frequency was taken.

Analysis of oscillograms of voltage at exit of generator has shown that range value of voltage at exit of generator is:

$$U_{G.A} = 5U_{G.E},$$

where $U_{G.E}$ –effective value of voltage at exit of generator, V.

At absence of load at exit of rectifier a direct component of impulse voltage is:

$$U_{R.E} = U_{T.A},$$

where $U_{T.A}$ –range of voltage atexitof step-up transformer.

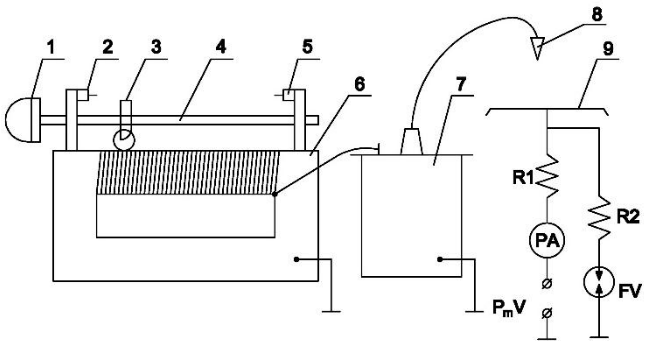

Fig.4. Diagram stand for study of VAF streamer form of corona discharge:

1 - motor with gear type RD-54; 2,5 – arresters; 3 – brush; 4 – spiral roller; 6 – autotransformer; 7 – source of high voltage; 8 – corona needle; 9 – grounded plane; PmV – connecting terminals for potentiometer KSP-4; PA – micro ammeter; R1, R2, FV – spark-protecting circuit

Effective voltage at exit of rectifier:

$$U_{RE} = 1{,}2\, U_{T.A}.$$

Range value of impulse voltage at exit of circuitry of rectification is:

$$U_{RA} = 2U_{T.A.}$$

Oscillograms of impulse voltage and current streamer form of corona discharge are presented in Fig. 3 and 4. In oscillograms it is seen that discharge current is stable up to frequency of 200 Imp^{-1} and character of its change is adequately described by previously obtained analytical dependences [3] At exceeding of frequency of more than 200 Imp^{-1} stability of discharge process is disturbed and gains a character of random. This relates both to type of voltage impulse, and to discharge current (Fig.4). Hence it can be concluded that at available parameters of circuitry a feed stability of discharge process is kept up to frequency of 200 Imp^{-1}. At further enhancement of frequency of impulse process the neutralization of bulk charges in discharge gap is not fully completed, and created by it opposite, to main electric field, electric field impacts on range of voltage and current which accordingly impacts on their stability.

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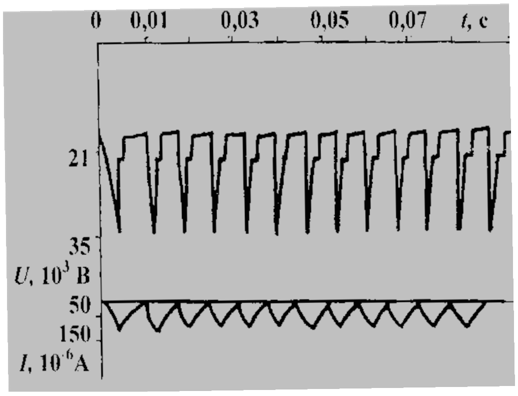

Fig.5. Oscillograms of voltage (upper) and current (lower) streamer form of corona discharge at frequency of 180 imp^{-1}

Obtained oscillograms of voltage and current streamer form of corona discharge confirmed the hypotheses about possibility of stabilization of discharge processes in electric field corona discharge at combination in one discharge gap of independent and dependent discharges.

VAF streamer form of corona discharge for preliminary analysis was compared to VAF corona discharge of direct voltage (Fig.5). Comparative VAF for streamer form of corona discharge was taken for frequency of 50 Imp^{-1}. From features it is seen that initial voltage ignition of discharge at direct voltage is 7x10^3 V, and at impulse voltage is 4x10^3 V. On VAF it is seen that at the same effective values voltage current streamer form of corona discharge more current corona of direct voltage. At voltage 2x10^4 V current streamer form of discharge is twice more. This fact together with stability of discharge process allows making preliminary conclusion that electric gas purification in electric fields of streamer form of corona discharge will be substantially efficient than in fields of corona discharge of direct voltage.

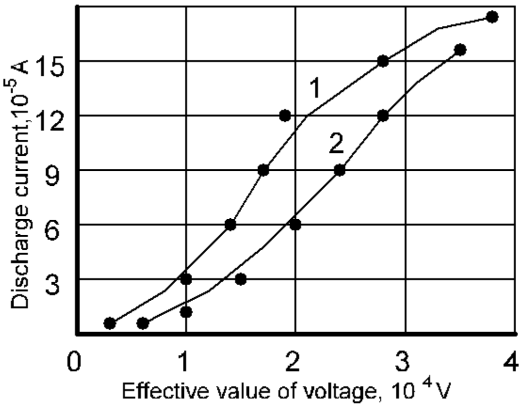

Fig.6. Comparative VAF corona discharge for effective values of impulse (1) and direct (2) voltage

With purpose of identification of dependence of VAF from frequency of applied impulse the VAF family for various frequencies of span 20…220 Imp^{-1} was taken. These VAF were taken from zero value of impulse voltage, to spark breakdown of discharge gap. From VAF family it is seen that by increasing of frequency of impulse voltage an electric strength of discharge gap is increased. If at frequency of 20 Imp^{-1} breakdown occurs at voltage 3x10^4 V, then at frequency of 220 imp^{-1} breakdown occurs now at 4x10^4 V.

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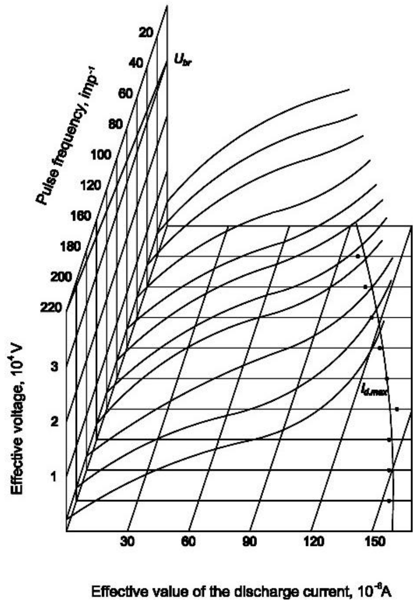

Fig.7. VAF Family of streamer form of corona discharge for system electrodes «needle-plane».

At the same time, by increasing of electric strength of discharge gap a peak current discharge is increased: $9{,}2x10^{-5}$ and at frequency of 20 Imp^{-1} and $1{,}6x10^{-4}$ and at frequency of 220 Imp^{-1}. Peak current discharge was fixed at pre-disruptive values of voltage. Some reduction of initial voltage ignition of discharge at increase of frequency of impulse is also noted.

Analysis of measurements results (Table) shows that mirrorreflection power significantly depends on frequency of impulse voltage and increases up to frequency of 200 Imp^{-1}, and then reduces. This is because for circuitry of feed the maximum frequency of stability of streamer form of corona discharge is 200 Imp $^{-1}$. At this frequency the mirror reflection power exceeds for 2,63 times the similar power at corona discharge of direct voltage. Similarly, value of surface charge and its density are increased. Hence it can be concluded that in electric fields of streamer form of corona discharge sedimentation of aerosol particles will occur more efficiently rather than in electric fields of corona discharge of direct voltage. Correctness of this conclusion is also related to value of strength of electric fields at feeding of impulse voltage is greater than strength of fields at feeding of direct voltage of corona discharge of direct and impulse voltages.

V. CONCLUSION AND FUTURE WORK

1. Enhancement of efficiency of gases purification from solid and liquid aerosol particles in electric fields might be achieved by use of streamer form of corona discharge allowing briefly enhance voltage in discharge gap above disruptivethreshold of direct voltage at stability of discharge processes on frequency and range. Stability of discharge current of streamer form of corona discharge is observed up to some frequency of impulse voltage, and depends on parameters of circuitry of feed.

2. Initial voltage ignition of discharge at direct voltage is $7x10^3$ V, and at impulse voltage – $4x10^3$ V. At the same effective values, voltage of current of streamer form of corona discharge is higher than current of corona of direct voltage. At voltage $2x10^4$ V current of streamer form of discharge is twice more. stability of discharge process allows making preliminary conclusion that electric gas purification in electric fields of streamer form of corona discharge will be substantially efficient than in fields of corona discharge of direct voltage.

3. From VAF family it is seen that by increasing of frequency of impulse voltage an electric strength of discharge gap is increased. If at frequency of 20 Imp^{-1} breakdown occurs at voltage $3x10^4$ V, then at frequency of 220 Imp^{-1} breakdown occurs now at $4x10^4$ V. At the same time, by increasing of electric strength of discharge gap a peak current discharge is increased: $9{,}2x10^{-5}$ and at frequency of 20 Imp^{-1} and $1{,}6x10^{-4}$ and at frequency of 220 Imp^{-1}. Peak current

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discharge was fixed at pre-disruptive values of voltage. Some reduction of initial voltage ignition of discharge at increase of frequency of impulse is also noted.

4. Use of streamer form of corona discharge for trapping of aerosol particles from flow of gases require separating of electric field for division of opposite bulk charges and creation of flow of unipolar bulk charges. With this purpose the system of electrodes «potential plane with corona needles – grounded plane» can be used.

5. Significant mutual screen impact of parameters of electrodes system «potential plane with corona needles – grounded plane», is detected that affects the value of discharge current. Preliminarily parameters of electrodes system might be selected on value of peak current discharge. However, these parameters require clarification at study of process of sedimentation of aerosol particles from flow air.

6. In electric fields of streamer form of corona discharge a Coulomb power is identified by parameters of elements of feed source, i.e. dynamic mode of process is obvious, unlike electric fields of corona discharge of direct voltage where such dependence practically does not exist.

7. Type of change in strength of electric fields in discharge gap identified by experiment adequately describes a theoretical dependence which depends on parameters of elements of circuitry feed.

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