Initiation of Electric Discharge in High-Conducting Mediums

V. Kuretz, G. Filatov, A. Yushkov

High Voltage Research Institute at Tomsk Polytechnical University
str. Lenina 2a, Tomsk, 634050, Russia
Tel./Fax: +7(3822) 418560
E-mail: Kuretz@hvd.tpu.ru

Abstract – The methods of electrodischarge treatment used in the technology of commercial production have an affecting factor produced by the electrical discharge in a liquid. The methods are implemented in HV electrohydraulic systems.

In electrodischarge technique the service water is usually used and it has the high conductivity value ($\gamma \geq 10^{-4}$ Ohms^{-1} cm^{-1}). Some production procedures employ solutions of higher conductivity values such as the cement solution or concrete mixes. Implementation of the electrodischarge processes in such mediums involves high energy losses during discharge formation and that requires the increase of the singe pulse energy and leads to the increase of energy consumption, fall in reliability and etc. So the search for new methods of the discharge formation in a high conductivity medium became necessary.

1. Introduction

The formation of a discharge channel in conducting mediums with high conductivity ($\gamma \geq 10^{-4}$ Ohms^{-1} cm^{-1}) is one of the problems of electrodischarge technique application. Said conductivity values is characteristic for the service water, cement and drill mud solutions and also for raw materials releasing conducting liquid dissolved components when are affected by action of electric discharges.

The increase of the conductance of processed liquid mediums leads to abrupt increase of pre-breakdown losses up to the energy value comparable with the pulse energy and this usually degrade considerably or completely terminate the process run. Different methods of discharge initiation are used for decreasing the energy losses during the pre-breakdown state and the local discharge channel formation. Most of the initiation methods involve the decrease, and some cases the avoidance, of energy losses for creation of the overheat instability on the potential electrode.

Par ex. an air bubble is led up to the potential electrode instead of being formed due to ion currents; the elevated electric field strength on the potential electrode is created due to parallel operation of the pulse current and voltage generators (PCG-PVG). These and other methods usually complicate an electrical circuitry and technique procedure of an installation. Moreover the methods cannot always be implemented in some conditions par ex. drilled wells or in stringy solutions.

In this paper the two methods of discharge initiation in conducting liquids which are easy to realize in electro-discharge techniques are considered. The first one involves the usage of the dielectric insert in the potential electrode, the second one – the usage of the charging current of a pulse generator capacitor battery flowing through the working gap. This methods should affect the conditions of the overheat instability development at the potential electrode.

2. Research Results

The pulse source was PCG having output voltage $U_0 = 30$ kV and energy $W_0 = 0.54$–1.35 J. The working chamber used in the investigations was a metal cap with the inner diameter 300 mm. The working gap length between the electrodes can vary from 10 to 50 mm. The probability of gap breakdown was estimated by monitoring the voltage pulse shape displayed by the storage tube scope C8-17. The potential electrode was fed by pulses of positive polarity. The liquid medium was the service water with the specific resistance $\rho \approx 3 \cdot 10^3\ \Omega \cdot$cm.

Let us consider the method of discharge initiation when the dielectric insert is placed into the potential electrode. The design of the potential electrode with the dielectric insert is shown in Fig. 1.

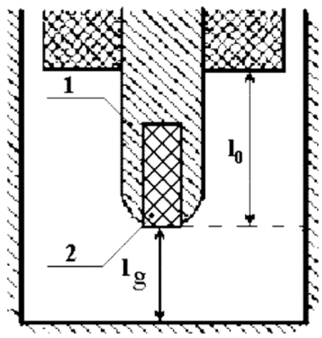


Fig. 1. Design of electrode system. *1* – potential electrode, *2* – dielectric insert

The usage of the dielectric insert as an initiating element is founded on the following expectations. It is known [1] the most week point of the electrode system is so called “triple point” located on the boundary of the potential electrode insulator ($\varepsilon \sim 2...3$), the electrode metal surface ($\varepsilon \sim \infty$) and the processed medium (ε ~ 80). Very often the discharge originates at this point though it is farther from the ground electrode than the length of the working gap. Usually that causes the potential electrode insulation to get out of order (breakdown and destruction). Some hold the opinion that this process involves concentrating and distortion of the electric field pattern near the potential electrode especially since the usage of the dielectric insert in gaseous switches for stabilizing the switching time is well known [2]. We suppose the location of "triple point" right in the working gap can considerably improve conditions for the overheat instability origin near the potential electrode due to the local electric field strength increase and, therefore, the decrease of the time span preceding the moment of discharge formation [3].

We ran experiments for the service water breakdown at the pulse energy W_0 = 0.54 kJ and voltage U_0 = 30 kV with different dielectric materials of the insert. The gap length varied 10 mm to 50 mm. The probability of gap breakdown was estimated. Results are shown in Table 1.

Table 1

Material of the insert	Gap length, mm				
	10	20	30	40	50
	Breakdown probability, %				
PEHD	81	77	69	60	44
PELD	78	74	65	58	37
PVS	75	71	64	54	38
Silicon	73	67	60	52	35
Rubber	46	34	18	7	2
Cloth laminate	45	32	16	6	1
No insert	40	26	9	1	0

The results show the different insulating inserts located at the potential electrode end increase the breakdown probability compared to gap breakdown without the insert by ~ (15…22%). That proves the insert affects the overheat instability formation nearby the potential electrode. Different materials of the insulating insert exert different effects on the breakdown probability. High density PE showed the best quality but rubber and cloth laminate had no effects on the breakdown probability. Taking into account that all tested dielectric materials had permittivity values close to each other the argument that the field gets distorted nearby the potential electrode and thus has effect on pre-breakdown processes is a vexed question.

For more detailed study of the process of discharge channel formation using a dielectric insertion, optical investigations were carried out. Experiments were made in technical water at the reduced level of the pulse energy W_0 = 45 J, U_0 = 30 kV.

Comparing the static discharge pictures for the electrode system with the insertion (Fig. 2, *a*) and usual "tip-plain" electrode system (Fig. 2, *b*), one can note that the discharge begins to develop from the triple point taken into the operating gap rather than from the electrode insulation.

a

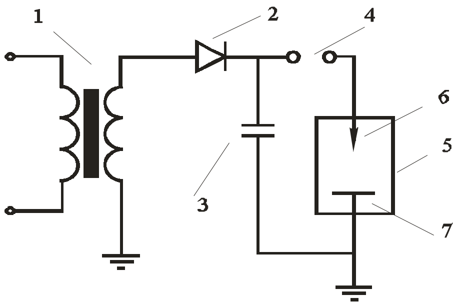
b

Fig. 2. The electrical discharge in water

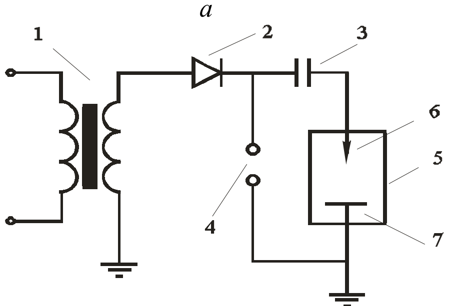
At running investigations the fact was registered that after 10…30 pulses applied to the electrode the insert does not have effects on the gap breakdown probability. This experimentally proved fact could not be explained by the field amplification nearby the potential electrode. When the tested insert is replaced by a new one made of the same material the gap breakdown probability increases again but after some number of pulses decays. The effect of the insert on the field distortion in the working gap was tested by placing it in the ground gap where the field pattern is almost uniform and the insert height was up to 80% of the gap length. No effect was observed in this position of the insert.

In our opinion the effects of the insert exerted on electrical breakdown can be qualitatively explained by following: at early applied pulses the space charge is generated in the insulating insert and produces the voltage across the boundary surface metal-insulator sufficient to cause breakdowns of microgaps. Bubbles of gas are generated at that and they initiate the breakdown of the working gap. As the space charge increases the voltage across microgaps decreases and the process of gas generation terminates, therefore after applying some number of pulses the insert has no effects on the discharge process in the gap. So the discharge initiation by the insulating insert involving processes in the boundary layer metal-insulator can be used in procedures where a single action of pulses is acceptable. At a multipulse treatment process this method of initiation can not be suggested.

The second method of initiation involves the usage of the capacitor battery charge current for decrease of the time span required for the overheat instability to be developed nearby the potential electrode [4]. Two schematics of the working gap connection are shown in Fig. 2. The schematic of Fig. 2, *a* is typical where the discharge gap is separated from the pulse generator by a switch. According to Fig. 2, *b* the working gap is connected in the charging circuit of the pulse generator. Consequently the charging current flows through the working gap until a pulse is generated.



a



b

Fig. 3. High-voltage generator schema. *1* – high-voltage transformer, *2* – rectifier, *3* – capacitor batter, *4* – shark gap, *5* – working chamber, *6* – high-voltage electrode, *7* – grounded electrode

If the time of the overheat instability development is small enough ($t_0 \ll t_c$) then one can expect the gaseous bubble generation before the moment the pulse of generator is applied. Bubbles generated during the period of capacitor battery charging will initiate the working gap breakdown.

If the flowing charging current and the electric field strength deviation nearby the potential electrode can not develop the overheat instability of a liquid yet this volume of a liquid will have the elevated temperature and the conditions for the overheat instability development will be improved at pulse applying.

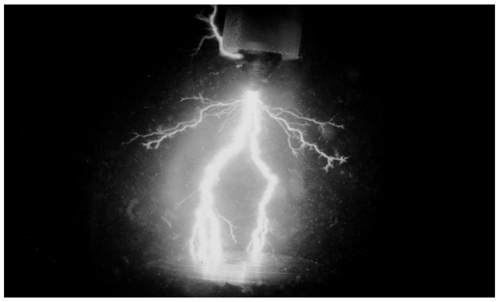
Tests were made with the service water as well with water cement solutions using the same chamber and electrode system. Table 2 presents results of breakdown probability estimation for the service water.

Table 2

Working gap length, mm	Pulse energy, kJ			
	0.54		1.35	
	Fig. 2, *a*	Fig. 2, *b*	Fig. 2, *a*	Fig. 2, *b*
10	100	100	100	100
20	90	100	100	100
30	65	85	100	100
40	55	65	94	100
50	10	46	71	95

Table 2 shows the breakdown probability of working gaps increases when the charging current of the capacitor battery is used. The fact is more noticeable at the pulse energy values 0.54 kJ as the pre-breakdown losses in our electrode system are comparable with the pulse energy. Obtained data show that the discharge initiation in such conducting mediums as water cement solutions also takes place.

For studying processes occurring in the operating gap during flowing the capacitor battery charging current, optical investigations were carried out. Experiments were made in technical water. The pulse parameters are: $W_0 = 45$ J, $U_0 = 30$ kV.



a

b

Fig. 4. The electrical discharge in water

Comparing the static discharge pictures obtained when the charging current was flowing through the operating gap (Fig. 4, *a*) and without current flowing (Fig. 4, *b*), it was noted that in most cases, the discharge started developing from the tip rather than from the electrode insulation. It should be noted also that the number of leaders covering the most part of the operating gap decreases when the current flowing through the operating gap is employed as an initiating factor.

3. Conclusions

Results of the work prove:

1. The usage of the insulating insert in the potential electrode as an initiating element or the charging current flow through the working gap allows to increase the breakdown probability in conducting mediums.
2. The usage of the insulating insert is advantageous in electrode techniques where a few pulses are in service.
3. The circuits providing the charging current running through a working gap can be suggested for all electrodischarge techniques especially for treatment of conducting liquids.

The considered methods of the discharge initiation can be used in creation of simple and reliable HV electrohydraulic equipment.

References

[1] K.A. Naugolnih, N.A. Roy, *The electric breakdown in water,* Moscow, Nauka, 1971, 155 pp.

[2] V.Ya. Ushakov, *The isolation of installations of a high voltage,* Moscow, Energoatomizdat, 1994, 496 pp.

[3] V.Ya. Ushakov, *The electric pulse breakdown in liquids,* Tomsk, TPI Publishing, 1975, 256 pp.

[4] V.I. Kuretz, G.L. Lobanova, G.P. Filatov, A.Yu. Yushkov, Surface engineering and applied electrochemistry, No. 1, 76–80 (2003).