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Fig. 1

Figure 1: Fig. 1

Abstract

Full Text

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SUBSTANTIAL REDUCTION OF MEAN BREAKDOWN GRADIENTS IN LONG DISCHARGE GAPS ON AN OBLIQUE-ANGLED VOLTAGE WAVE

(Presented by Academician L. A. Artsimovich on 26 III 1960)

It is known that the discharge voltage of a gap U_p depends on the shape of the applied voltage wave, which is connected with the physical features of the mechanism of spark development. Investigations carried out in the Laboratory of High-Voltage Gas Discharge of the G. M. Krzhizhanovsky Power Engineering Institute of the Academy of Sciences of the USSR have revealed the influence of the individual stages of the spark on the formation of breakdown⁽¹⁻⁴⁾. Recently it has been possible to obtain some interesting results on a substantial reduction of the mean discharge gradients E_{sr} for a rod-plane gap ($d = 2$ cm, end rounded) of length 1-3 m.

In Fig. 1b the basic circuit of the experimental setup is shown. The rate of rise of the voltage across the gap S_0 is determined by the time constant $T = R_1 C_1$ and can be regulated over wide limits by varying the values of R_1 , C_1 , and the voltage at the output of the GIN, U_r . The parameters of the discharge circuit and the value of U_r were selected so that the discharge occurred on the front of the voltage wave.

Fig. 1. Electrical circuit of the experiments. I.Sh.—measuring spheres.
 $C_1 = 850 \div 2200$ pF, $C_2 = 2$ μ F, $R_1 = 5 \div 700$ k Ω , $R_T = 400$ Ω ,
 $R_2 = 130$ k Ω , $R_3 = 75$ Ω

The voltage was recorded by means of an oscilloscope and a capacitive voltage divider C_1 - C_2 , calibrated by measuring spheres I.Sh., $d = 150$ cm. A typical oscillogram of the voltage in the discharge gap is given in Fig. 1a. In the experiments the discharge time t_p was varied, by means of the circuit parameters, within the range $20 \div 700$ μ s.

The discharge characteristics of the rod-plane gap are given in Fig. 2. Attention

Fig. 2. Dependence of the breakdown voltage U_p of a rod–plane gap under an oblique-angled wave on the discharge time t_p . 1 – $S_0 = 100$ cm, 2 – 200 cm, 3 – 250 cm, 4 – 300 cm, 5 – 375 cm

Figure 2: Fig. 2. Dependence of the breakdown voltage U_p of a rod–plane gap under an oblique-angled wave on the discharge time t_p . 1 – $S_0 = 100$ cm, 2 – 200 cm, 3 – 250 cm, 4 – 300 cm, 5 – 375 cm

is drawn to the fact that all curves $U_p(t_p)$ have a minimum in the region $t_{p,\min} = 150 \div 180 \mu\text{s}$. In this case the discharge voltages at the minimum points $U_{p,\min}$ are substantially smaller than the electric strength of an analogous gap under direct and alternating voltages. The mean discharge gradients $E_{\text{sr},\min}$ in the gap $S_0 = 200 \div 300$ cm at $U_{p,\min}$ are $3.5 \div 3.0$ kV/cm, which corresponds to E_{sr} observed previously in so-called “anomalous” flashovers under direct voltage in screen-wall gaps 370 cm long⁽⁵⁾. When the time is decreased, $t_p < t_{p,\min}$, the discharge voltage rises sharply.

and in the region of small times reaches very large values. An increase in $t_p > t_{p,\min}$ is accompanied by a significantly slower rise of U_p , which at large t_p apparently tends toward the strength of the gap under constant voltage.

An explanation of the obtained dependences $U_p(t_p)$ can be given on the basis of a qualitative analysis of the predischARGE processes in the gap. The formation of predischARGE processes (pulse and avalanche forms of corona, leader) that precede breakdown takes place over time. Therefore, from the moment the discharge arises until breakdown is completed in the gap, considerable overvoltages are possible, caused by the rise of the voltage during this time. This overvoltage increases with increasing steepness of the wave front and thereby determines the large values of U_p in the region of small times t_p . Thus, the rise of the left branch of the curve $U_p(t_p)$ from the point $t_{p,\min}$ is due to the inertia of the predischARGE processes.

Fig. 2. Dependence of the breakdown voltage U_p of a rod–plane gap under an oblique-angled wave on the discharge time t_p . 1 – $S_0 = 100$ cm, 2 – 200 cm, 3 – 250 cm, 4 – 300 cm, 5 – 375 cm

With increasing time t_p , the influence of the inertia factor on U_p decreases; however, the blocking action of the space charge formed in the process of development of the avalanche form of corona begins to increase. The space charge of the avalanche corona monotonically fills the near-electrode region, stabilizes and equalizes the gradients in it. At the same time, there is a sharp increase in the electric strength of the near-electrode region, and with this the U_p of the gap also increases.

The blocking action of the avalanche corona was studied in detail by the authors under alternating voltage of industrial frequency. Using cylindrical electrodes with a sharpened lower edge, it was possible to obtain strengthening of the rod–plane gap up to $E_{\text{av}} = 15 \div 22$ kV/cm. The discharge characteristics of such

Fig. 3

Figure 3: Fig. 3

gaps are given in Fig. 3, 1, 2, 3. There, for comparison, curve 4 is also plotted for a rounded rod electrode. The optical pattern of the predischARGE processes at the lower edge-

of the cylindrical electrode had the form of a uniformly luminous sheath. A disturbance of the uniform distribution of the avalanche corona sharply reduced the value of U_p .

Fig. 3. Discharge characteristics of rod-plane gaps under alternating voltage. 1, 2, 3—for cylindrical electrodes with a continuous lower edge: 1— $d = 10$ cm, 2—6 cm, 3—2 cm; 4—for a rounded rod, $d = 2$ cm

The shielding action of the avalanche form of the corona must also appear on rounded rod electrodes with $d = 2$ cm at $S_0 > 100$ cm, since here the rod may be regarded as a well-corona-producing point. Excluding the shielding action of the avalanche corona, one can obtain reduced values of U_p in comparison with the strength under direct and alternating voltages. It is precisely these conditions that correspond to breakdown on an oblique-front voltage wave at relatively small t_p , when the space charge of the avalanche corona practically has no time to form. $U_{p, \min}$ is obtained at such a voltage-rise rate at which the inertia factor in the development of the discharge already has little effect on the magnitude of U_p , but t_p is still not large enough for the space charge of the avalanche corona being formed to exert a noticeable shielding action. A further increase of t_p increases the effectiveness of formation of the space charge of the avalanche corona, which also accounts for the increase of U_p to the right of the point $t_{p, \min}$. In Fig. 4 the dependence $E_{av, \min}(S_0)$ is plotted; there, for comparison, the curves $E_{av}(S_0)$ for the rod-plane gap under direct ($E_{av=}$) and alternating ($E_{av\sim}$) voltages according to ^(6, 7) are also given. A characteristic feature of the curves $E_{av, \min}(S_0)$ and $E_{av\sim}(S_0)$ is a decrease of the average gradients with increasing S_0 , whereas $E_{av=}$ in the investigated range of lengths S_0 remains practically constant.

Since, under the action of an oblique-front wave or alternating voltage, the time for formation of unipolar space charge is limited, the region of its propagation is also limited. The latter is due to the fact that the maximum radius of ion removal is a function of the ion mobility, the distribution of gradients in the near-electrode region, and the duration of voltage application. The ion mobility has a finite value and within known limits is independent of E . At sufficiently large S_0 , the gradients in the near-electrode region also depend little on S_0 , and, what is essential, their magnitude is stabilized by the space charge. On an oblique-front wave the duration of voltage action is limited by t_p ; under alternating voltage—by the time

Fig. 4. Dependence of the average discharge gradients on the length of the rod

Fig. 4

Figure 4: Fig. 4

—plane gap. $E_{av\sim}$ —according to data of (6); $E_{av=}$ —according to data of (7)

on the order of a half-period, during which the unipolar space charge in the near-electrode region does not change its sign. Therefore, in contrast to direct voltage, where the time t_p can be arbitrarily large, it should be assumed that, under the action of an oblique wave and alternating voltage, the region of propagation of the unipolar space charge is limited and, what is especially important, is practically independent of S_0 . But since, with increasing S_0 , the influence of the limited strengthened region decreases, the falling character of the curves $E_{av}(S_0)$ on an oblique wave and alternating voltage becomes understandable.

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REFERENCES CITED

1. E. N. Brago, I. S. Stekolnikov, *Izv. AN SSSR, OTN*, No. 11 (1958).
2. I. G. Pulavskaya, I. S. Stekolnikov, Scientific-technical bulletin, No. 9, Electrical Engineering, Leningrad Polytechnic Institute, 1958.
3. I. S. Stekolnikov, in: Proceedings of the Energy Institute named after G. M. Krzhizhanovsky, Academy of Sciences of the USSR, Electric Power Engineering, issue 1, 1959.
4. I. S. Stekolnikov, *Izv. AN SSSR, phys. ser.*, **23**, No. 8 (1959).
5. A. Bouwers, A. Kuntke, *Zs. f. techn. Phys.*, No. 8, 209 (1937).
6. N. N. Tikhodeev, A. N. Tulinov, *Elektrichestvo*, No. 3 (1958).
7. I. K. Fedchenko, M. E. Ierusalimov, *Izv. vyssh. uchebn. zaved.*, Energy, No. 7 (1959).

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