POWER DESCRIPTIONS OF A STORM CLOUD OF TROPOSPHERE OF EARTH: FEATURES OF THEIR CALCULATION AND APPLIED UTILIZATION

Purpose. Implementation of calculation estimation of such basic power descriptions of the system is a «storm cloud - earth», as total charge of $q_c$, electric potential of $\phi$, electric energy of $W_e$ and amplitude-temporal parameters (ATP) of pulse current $i_L(t)$ in the channel of a long air spark discharge of cloud on earth. Methodology. Electrophysics bases of technique of high voltages and large currents, theoretical bases of the electrical engineering, theoretical electrophysics, theory of the electromagnetic field and technique of the strong electric and magnetic fields. Results. The results of calculation estimation of basic power descriptions are resulted in the overhigh voltage electrophysics calculation system a «storm cloud - earth». To such descriptions of a storm cloud behavior: total electric charge of $q_c$, concentrated in a storm cloud of spherical form of the set volume with the shallow dispersible negatively charged including as particulate dielectric matters the set by a middle closeness; electric potential of $\phi$, is in the spherical volume of a storm cloud of the set size; electric energy of $W_e$ accumulated in the spherical volume of a storm cloud of the set radius of $R_0$; PTP (amplitude of $I_{L\text{int}}$ and duration of $\tau$ at level 0.5$I_{L\text{int}}$) of aperiodic impulse of current $i_L(t)$ of linear lightning in the plasma channel of a long air spark digit of a storm cloud on earth. The ground of possibility of the use is given in close practical calculations in place of the real storm cloud of the simplified calculation model of a storm cloud, containing the spherical volume of $V_0$ by the radius of $R_0$ is shown that at $R_0$=985 m and accordingly $V_0$=4·10^7 m^3 in the examined model of a storm cloud his indicated power descriptions arrive at the followinges numeral values: charge of $q_c$≈55.6 C, potential on the outward surface of cloud of $\phi$≈506 MV, electric energy of $W_e$=14.1 GJ in a cloud and amplitude of aperiodic impulse of current of $I_{L\text{int}}$≈262.1 kA at duration of his flowing $\tau$=142.4 µs in the plasma channel of a long air spark digit of cloud on earth. This calculation information well correlates with the known experimental information, characteristic for the short shots of lightning in surface objects. The receive results will be instrumental in possibility of prognostication of a sticky storm wicket specialists at the presence of only minimum initial information about a storm cloud in earthly troposphere. Originality. First at the analysis of a surface objects. The receive results will be instrumental in possibility of prognostication of a sticky storm wicket specialists at the presence of only minimum initial information about a storm cloud in earthly troposphere. Originality. First at the analysis of a surface objects. The receive results will be instrumental in possibility of prognostication of a sticky storm wicket specialists at the presence of only minimum initial information about a storm cloud in earthly troposphere. Referencees 12, figures 2.

Key words: atmospheric electricity, storm cloud, accumulated charge, electric potential and energy of cloud, current in the channel of discharge of cloud on earth, calculation, experimental information.

Introduction. One of the problematic tasks in the field of atmospheric electricity and lightning protection of terrestrial and near-earth air objects still remains one that is connected with the determination, with minimal initial information about the thunderstorm situation in the area of this or that territory of the planet studied by specialists (engineers and meteorologists) energy characteristics of the thundercloud in the Earth's troposphere. Such characteristics of a thundercloud include: firstly, the total electric charge $q_c$ accumulated in such a cloud; secondly, the electric potential $\phi$, in the volume of a thunderstorm cloud; thirdly, the electric energy $W_e$ accumulated by fine-dispersed inclusions (for example, small drops and water vapor, small granules and ice crystals and small solid dielectric particles [1, 2]) of the atmospheric cloud under consideration in the «storm cloud - earth» electrostatic system; fourth, the probable amplitude-temporal parameters (ATPs) of the pulsed current $i_L(t)$ in the channel of the high-current discharge of a thunderstorm cloud to the ground or to the protected object. Their forecast of a possible thunderstorm threat to land-based objects and aircraft caught up in the area of the atmospheric cloud depend on these data. Knowledge of indicated energy characteristics of a thunderstorm cloud makes it possible to predict a thunderstorm situation in...
the investigated area of terrestrial land, and also in a certain way extends knowledge of people in the field of atmospheric electricity and the physics of a long air spark discharge (lightning) and the consequences of its (this high-current discharge) action on the protected objects and their environment. It should be noted that usually under a thundercloud, meteorologists understand a cumulonimbus cloud for which a year-round thundercloudburst has the shape of a sphere of radius $R_0$ that is close to the Earth's troposphere, almost all water vapor, and various kinds of clouds in temperate latitudes which contains 4/5 of the entire mass of the atmospheric cloud, almost all water vapor, and various kinds of clouds develop [1, 3]. In this connection, an approximate determination by calculation of the quantities $q_\Sigma$, $\varphi_\Sigma$, $W_0$ and ATPs of the discharge current $i_L(t)$ in the superhigh-voltage electrostatic system «thundercloud - earth» in which the atmospheric cloud has even a horizontal base of 1000 m and a height of up to 11 km in temperate latitudes which contains 4/5 of the entire mass of the atmosphere, almost all water vapor, and various kinds of clouds develop [1, 3]. In this connection, an approximate determination by calculation of the quantities $q_\Sigma$, $\varphi_\Sigma$, $W_0$ and ATPs of the discharge current $i_L(t)$ in the superhigh-voltage electrostatic system «thundercloud - earth» in which the atmospheric cloud has even a horizontal base of 1000 m and a height of up to 11 km in temperate latitudes which contains 4/5 of the entire mass of the atmosphere, almost all water vapor, and various kinds of clouds develop [1, 3].

The goal of the paper is the calculation estimation of such basic energy characteristics of the «lightning discharge of the cloud to the earth» system as the charge $q_\Sigma$, the potential $\varphi_\Sigma$, the energy $W_0$ and the amplitude-temporal parameters of the pulsed current $i_L(t)$ in the channel of the long air spark discharge of the cloud to the earth.

1. **Problem definition.** For convenience in analyzing the distribution of atmospheric electricity in the Earth's troposphere, let us consider one of the special cases when the thundercloud has the shape of a sphere of radius $R_0=985$ m (Fig. 1), inside which, with an average volume density $N_0=5\times10^7$ m$^{-3}$, solid dielectric particles with a radius $r_0=10\times10^{-6}$ m are mainly placed [1], each of which at the stage of formation of the cumulonimbus cloud obtained by electrifying in the warm ascending air streams of the Earth's atmosphere a negative electric charge of $q_0=-2.78\times10^{-16}$ C and at the stage of formation of a thunderstorm cloud was freed from the covered them electrically neutral molecular water dipoles [2]. The choice of the numerical value of radius $R_0$ of the cloud was due to the fact that in order to simplify the calculations, as in [2], its initial calculation volume $V_0=4\pi R_0^3/3=4\times10^9$ m$^3$, and this numerical value of $R_0$ follows.

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From (1) at accepted initial data when $q_0=2.78\times10^{-16}$ C, $N_0=5\times10^7$ m$^{-3}$ and $V_0=4\times10^9$ m$^3$, it is following than in the considered case the value of $q_\Sigma=-55.6$ C.

The modulus of the numerical value of the total electric charge $q_\Sigma=55.6$ C in the considered lightning cloud obtained in accordance with (1) completely corresponds to the normalized charge $q_L=(50\pm10)$ C for a short lightning strike with a pulsed discharge aperiodic current of a temporal shape 10 μs/350 μs to ground technical facilities that satisfy III-IV lightning protection levels according to the requirements of the International Standard IEC 62305-1:2010 [5, 6].

Fig. 1. Schematic view of a simplified calculation model of a negatively charged thundercloud of spherical shape located above the Earth's flat surface (1 – cloud, 2 – electron, 3 – flat surface of the Earth)

In addition, we indicate that the used numerical value of the averaged volume charge density of the
lightning cloud under investigation, defined as \( \sigma_t \approx q_0 N_0 \approx -1.39 \cdot 10^8 \) C/m², corresponds to known experimental data for the mean value of the space charge density in a thunderstorm cloud [1, 2].

3. Calculation estimation of the electric potential \( \varphi_r \) of a thunderstorm cloud. Applying the approach given in [7] to finding in the cloud the values of the electric potential \( \varphi_r \) for the radial distribution of the required potential \( \varphi_r \) in the simplified model of the thundercloud, we obtain:

\[
\varphi_r = q_\Sigma (3R_0^2 - r^2) / (8\pi\varepsilon_0 R_0^3),
\]

where \( r \) is the current radius in the spherical volume of the cloud; \( \varepsilon_0 = 8.854 \cdot 10^{-12} \) F/m is the electric constant [4].

From (2) at \( r = 0 \) for the electric potential \( \varphi = \varphi_0 \) in the center of the assumed thunderstorm cloud, we find:

\[
\varphi_0 = 3q_\Sigma / (8\pi\varepsilon_0 R_0).
\]

At \( r = R_0 \) from (2) for the electric potential \( \varphi = \varphi_0 \) the following calculation relation follows on the outer surface of the sphere of a thunderstorm cloud:

\[
\varphi_0 \approx q_\Sigma / (4\pi\varepsilon_0 R_0).
\]

Analysis of the above calculation expressions (3), (4) shows that the electric potential \( \varphi_0 \) in the center of the thunderstorm cloud is 1.5 times higher than the electric potential \( \varphi_0 \) acquired by the outer spherical surface of the cloud. Hence, the deep mechanism of charge «recharge» of the plasma channel of a long spark discharge of a thundercloud on the ground or a protected technical object becomes physically more understandable in the theory of atmospheric electricity. After all, at such a radial distribution in the thundercloud of the electric potential \( \varphi_r \) in the case of an electric discharge in the «thunder cloud - earth» system (see Fig. 1) of an air gap of length \( (H_0 - R_0) \) to compensate the decrease of the electric potential \( \varphi_0 \) on the outer surface of the cloud to it from inner zones of a cloud with a higher electric potential \( \varphi_e \), the electric charges (in our case free electrons) will «leak» which replenish the carriers of the electric current \( i(t) \) in the channel of the discharge itself.

Numerical estimation by (3), (4) of the electric potentials inside and outside the thunderstorm cloud under consideration at \( q_\Sigma = -55.6 \) C and \( R_0 = 985 \) m indicates that in this case the required values are approximately equal by modulus to \( \varphi_0 \approx 759 \) MV and \( \varphi_e \approx 506 \) MV. From the qualitative data known to the author for the electric potential \( \varphi_e \) of a thunderstorm cloud, only its numerical value of about 100 MV, given in [8], can be indicated.

In order to verify the reliability of the obtained electric potential \( \varphi_e \approx 506 \) MV of the thunderstorm cloud under consideration, let us use a numerical estimation of the value of the electrostatic field strength \( E_R \) near its outer spherical surface \( (r = R_0) \). On the one hand, \( E_R \approx \varphi_e / R_0 \approx 513 \) kV/m [4]. On the other hand, in order to find \( E_R \) in the investigated electrostatic case, we apply a more accurate analytic relation of the form [2, 7]:

\[
E_R \approx q_\Sigma / (4\pi\varepsilon_0 R_0^2).
\]

From (5) at \( q_\Sigma = 55.6 \) C and \( R_0 = 985 \) m we find that \( E_R \approx 515 \) kV/m. It is evident that both numerical values given for \( E_R \) practically coincide. In this connection, we can speak of the efficiency of the calculated ratios (1), (4) that determine the total charge \( q_\Sigma \) in the adopted thunderstorm cloud model and the electric potential \( \varphi_e \) of the outer spherical surface of the cloud under investigation. By the way, the value of \( E_R \) by (5) is the largest in the radial distribution of the electrostatic field strength in the spherical volume \( V_0 \) of the cloud. As is well known, for this high \( E \)-field according to a relation of the form [2, 7]:

\[
E_r = q_\Sigma r / (4\pi\varepsilon_0 R_0^3),
\]

at \( r = 0 \) the strength \( E_r \) will be equal to zero (at \( r = R_0 \) (6) becomes (5) and determines the level of the \( E \)-field on the outer surface of this cloud).

The data presented for the radial distribution of the electrostatic field strength \( E_r \) in the «thunder cloud - earth» system unequivocally indicate that in the case of a homogeneous (in the composition [3]) character of the change in the carriers of electricity in the spherical volume \( V_0 \) of the assumed thunderstorm cloud, the development of electron avalanches [1, 8] which are the forerunner of the appearance in our system of lightning (spark breakdown in the troposphere of the Earth of a long air gap) will always start from the outer surface of the cloud. Note that the indicated numerical value of \( E_R \approx 515 \) kV/m at the accepted atmospheric conditions approaches the critical \( E \)-field value corresponding to the pre-breakdown stage of processes in the long air gap our system of the length \( (H_0 - R_0) \) of our system [1, 8].

4. Calculation estimation of the electrical energy \( W_0 \) of a thunderstorm cloud. Preliminary calculation estimations of the numerical values of the electric energy \( W_0 \) accumulated in the storm cloud under investigation revealed the presence of a number of features in its determination. Thus, it turned out that the direct application of the principles and formulas from [9] for its electric capacitance to the calculation system «thunder cloud - earth» (see Fig. 1) leads to erroneous results in calculating the values of the \( W_0 \) energy of a thunderstorm cloud. In order to demonstrate the results obtained with respect to the energy \( W_0 \) with such a calculated approach, we first start from the fact that at the electric potential \( \varphi_0 \) of the cloud found above (in Section 3) and the a priori zero earth electrical potential \( \varphi_0 = 0 \) for calculating the electrical energy \( W_0 \) for the «thunder cloud - earth» calculation system that is used, it remains to determine only the value of its electrical capacitance. The «direct» definition in the case under consideration \( (H_0 / R_0 = 3.04) \) of its electrical capacitance \( C_0 \), according to the recommended [9] for the inequality \( H_0 / R_0 \approx 1.5 \) an approximate formula of the form:

\[
C_0 = 2\pi\varepsilon_0 \sqrt{\ln(2H_0 / R_0)}.
\]

leads to significantly lowered values of the electrical capacitance in the calculation system «thunder cloud -
earth. For example, assuming the initial data \( H_0 = 3000 \text{ m} \) and \( R_0 = 985 \text{ m} \), according to (7), the value of \( C_0 \) is approximately \( C_0 \approx 30.8 \cdot 10^{-12} \text{ F} \). Therefore, the value \( W_0 = C_0 U_0^2/2 \) [4], where \( U_0 = (\varphi - \varphi_R) \) is the difference between the electric potentials of a thunderstorm cloud and a flat ground surface, assumes a numerical value of only 3.94 MJ for \( U_0 = 506 \text{ MV} \) and the huge volume \( V_0 = 4 \cdot 10^9 \text{ m}^3 \) of a thunderstorm cloud used by us. The reason for this is that (7) takes into account only the distribution of electric charge along the outer surface of the calculated sphere of radius \( R_0 \). It does not take into account the effect of the electric charge distributed with volume density \( \sigma = q_0 N_0 \) in volume \( V_0 = 4 \pi R_0^3/3 \) of this sphere. In this regard, the value of the electric energy \( W_0 \) of a thunderstorm cloud is recommended to be determined by the following approximate relationship:

\[
W_0 \approx 0.5 C_E U_0^2, \tag{8}
\]

where \( C_E = q_0^2 U_0 \) is the equivalent capacitance of the superhigh-voltage system «thunder cloud - earth».

It should be noted that when using (8) a some error is introduced into the approximate calculation of \( C_E \) and \( W_0 \) values, due to the previously described corresponding radial distribution of the electric potential \( \varphi \), over the spherical volume of the received thunderstorm cloud. However, this error is incommensurable small in comparison with the error introduced by (7) into the calculation of the electric capacitance and electric energy \( W_0 \) in our system «thunder cloud - earth».

From (8) at \( q_0 \approx 55.6 \text{ C} \) and \( U_0 \approx 506 \text{ MV} \), we find that with the recommended author's approach for the system «thunder cloud - earth» under consideration, the value of its equivalent electric capacitance \( C_E \) will assume a numerical value of about \( 1.1 \cdot 10^{-7} \text{ F} \), and the value of electric energy accumulated in it is \( W_0 \approx 14.1 \cdot 10^9 \text{ J} \) (as we see, it is almost 3578 times larger than with the use of formula (7) in calculating \( C_0 \) and \( W_0 \)). The author currently does not have quantitative data for \( W_0 \) by other researchers of atmospheric electricity in the world. It can only be assumed that if the total charge \( q_E \) by (1) and the electric potential \( \varphi_R \) by (4) are found correctly (we have given the above fairly convincing electrophysical justifications of these calculations), then the approximate determination by (8) of the value of the electric energy \( W_0 \) of the thunderstorm cloud is also correct.

5. Calculation estimation of the ATP of current \( i_L(t) \) in the thunderstorm discharge channel on the earth. For this estimation, with reference to the discharge circuit of the capacitance \( C_E \) of the thunderstorm cloud through the plasma channel in the air to the earth, we use the classical electrical engineering approach characteristic for electromagnetic processes in the RLC circuit [10]. First, we estimate the numerical value of the inductance \( L_k \) of a cylindrical plasma channel with the radius \( r_0 \) of a high-current spark discharge of a thunderstorm cloud in the air gap of length \( l = (H_0 - R_0) \) to the earth according to the following formula [11]:

\[
L_k = (2\pi)^{-1} \mu_0 l \ln(2l / r_0) - 1, \tag{9}
\]

where \( \mu_0 = 4\pi \cdot 10^{-7} \text{ H/m} \) is the magnetic constant [4].

From (9), at \( l = (H_0 - R_0) = 2015 \text{ m} \) and \( r_0 = 11.1 \cdot 10^{-3} \text{ m} \) [12] it follows that in our case the concentrated inductance \( L_k \) of the thunderstorm cloud discharge channel on the earth will take a value numerically equal to about 4.76 mH. When evaluating the numerical value of the active resistance \( R_k \) of a cylindrical lightning air discharge channel, we proceed from the fact that the line active resistance \( R_0 \) of the investigated high-current channel, according to the calculation-experimental data from [12] for the repetitive pulsed \( D \)-component of the artificial lightning current of the amplitude \( I_{\text{amp}} = 92.3 \text{ kA} \) (Fig. 2), where \( t_{\text{amp}} = 15 \mu \text{s} \) is the time corresponding to the first amplitude \( I_{\text{amp}} \) of the current) is numerically about 0.92 \( \text{\Omega/m} \). As a result, for the active resistance \( R_k \) of the thunderstorm plasma channel of the investigated cloud to the earth (see Fig. 1) we find that \( R_k = R_0 l_k \approx 0.92 \text{ \Omega \cdot m}^{-1} \times 3000 \text{ m} \approx 1.85 \text{ k\Omega} \). It is seen that in the case under consideration the inequality \( R_k > 2(L_k/C_E)^{1/2} \) is satisfied for the electrical parameters \( R_k, L_k \) and \( C_E \) of the discharge circuit under consideration. This means that an aperiodic current pulse \( i_L(t) \) will flow in the lightning current channel [10, 12].

For the ATP of the discharge current \( i_L(t) \) at an aperiodic law of its variation with time \( t \), the following calculation relation can be used [10, 12]:

\[
i_L(t) = U_0 [(a_2 - a_1) L_k]^{-1/2} \exp(-a_1 t) - \exp(-a_2 t), \tag{10}
\]

where \( a_1, a_2 \) are the pulsed current shape coefficients equal to \( a_1 = \delta - (\delta - a_0)^{1/2} \) and \( a_2 = \delta + (\delta - a_0)^{1/2} \), \( \delta = R_k/(2L_k) \) is the attenuation coefficient of discharge current; \( a_0 = (L_k/C_E)^{1/2} \) is the own circular frequency of the discharge current of a cloud.

The time \( t_{\text{amp}} \) corresponding to the amplitude \( I_{\text{amp}} \) of the lightning current of the discharge in accordance with (10) will be equal to the analytical relation known in electrical engineering [10]:

\[
t_{\text{amp}} = \ln(a_2/a_1)/(a_2 - a_1). \tag{11}
\]
For the obtained initial data \( R_e=1.85 \, \text{k\Omega} \), \( L_k \approx 4.76 \, \text{mH} \) and \( C_k=110 \, \text{nF} \), we see that in the case under consideration: \( \delta \approx 1.94 \times 10^{-7} \, \text{s}^{-1} \); \( \omega_k \approx 43.7 \times 10^{-13} \, \text{s}^{-1} \); \( \alpha_1 \approx 5 \times 10^{-13} \, \text{s}^{-1} \); \( \alpha_2 \approx 3.83 \times 10^{-13} \, \text{s}^{-1} \); \( t_{\text{lad}} \approx 11.47 \, \mu\text{s} \) (see Fig. 2, where the experimental time for the pulse amplitude of the artificial lightning current was about 15 \( \mu\text{s} \)). At \( U_0 \approx -506 \, \text{MV} \) and \( t_{\text{lad}} \approx 11.47 \, \mu\text{s} \), the calculated value of the amplitude of the lightning current for the investigated case according to (10) will be approximately \( I_{\text{lad}} \approx -262.1 \, \text{kA} \). The obtained quantitative values for \( t_{\text{lad}} \) and the amplitude \( I_{\text{lad}} \) of the current in the charge channel of the assumed thunderstorm cloud to earth are well correlated with the ATPs of the pulse current characteristic for short strokes of the linear lightning to ground objects satisfying the level of their lightning protection according to the stringent requirements of the International Standard IEC 62305-1:2010 [5, 6]. As for the duration \( \tau_p \) of the aperiodic lightning current pulse at the level 0.5 \( I_{\text{lad}} \) for our case it is approximately equal to \( \tau_p \approx 0.7R_c/C_k \approx 142.4 \, \mu\text{s} \). Thus, with minimal information on the electromagnetic situation in the zone of formation and development of a thunderstorm cloud (only in terms of its approximate dimensions and height of placement above the Earth’s surface), experts can reasonably predict a thunderstorm «picture» for the superhigh-voltage electrophysical system «thunder cloud - earth» under consideration.

Conclusions.

1. It is shown that by engineers and meteorologists a spherical cloud model with an outer radius \( R_0 \) and a volume \( V_0=4\pi R_0^3/3 \) can be adopted as a simplified calculation model of a thundercloud containing distributed over its spherical volume with an average density of \( N_0=5 \times 10^7 \, \text{m}^{-3} \) negatively electrified in the warm ascending air flows of the Earth’s troposphere, small solid dielectric particles with a radius of \( r_0=10^{-6} \, \text{m} \) and a charge of \( q_0 \approx -2.78 \times 10^{-16} \, \text{C} \). Varying the numerical values of the radius \( R_0 \) and, correspondingly, the volume \( V_0 \) of such a thundercloud, one can also change its basic energy characteristics within a wide range corresponding to the normative and technical documents in force in the world.

2. An example of a thunderstorm cloud of the Earth's troposphere of radius \( R_0=985 \, \text{m} \) and volume \( V_0=4 \times 10^7 \, \text{m}^3 \) at \( H_0=3000 \, \text{m} \) demonstrates the possibilities of the proposed approach in the field of atmospheric electricity investigations for the approximate determination by specialists of the modules of such its energy characteristics as the total electric charge \( q_c \approx 55.6 \, \text{C} \), electric potential at the center \( \phi_0 \approx 775 \, \text{MV} \) and on the outer surface \( \phi_R \approx 506 \, \text{MV} \) of the cloud, accumulated by fine-dispersed inclinations of the cloud electric energy \( W_c=14.1 \, \text{GJ} \) and ATPs of the aperiodic impulse current \( I_{\text{i0}} \) in the plasma channel of the long air spark discharge of the cloud to earth \( t_{\text{lad}} \approx 262.1 \, \text{kA} \); \( t_{\text{lad}} \approx 11.5 \, \mu\text{s} \); \( \tau_p \approx 142.4 \, \mu\text{s} \). The obtained quantitative data for \( q_c \), \( \phi_0 \), \( W_c \) and ATPs of lightning impulse current on the earth’s surface satisfy a number of requirements of the International Standard IEC 62305-1:2010 for short strokes of linear lightning to ground objects.

3. The results obtained will contribute to the possible fulfillment by engineers and meteorologists of the prediction of the electromagnetic situation in the area of formation and development in the Earth’s troposphere of a real thunderstorm cloud, previously reduced by the volume of \( V_0 \) occupied by it to an equivalent storm cloud of spherical shape with radius \( R_0 \). This approach, thanks to the developed physical and mathematical apparatus, makes it possible in an approximate form to find the indicated basic energy characteristics \( q_c \), \( \phi_0 \), \( W_c \) and ATPs of the channel current) of an equivalent thundercloud cloud and opens up certain new possibilities in the world practice of solving the actual problems of lightning protection of ground objects and in-flight aircraft that have found themselves in a hazardous zone of high electromagnetic influence on their electrical equipment (first of all, on their low-current electronics) of a thunderstorm cloud with its huge in terms of numerical indicators energy characteristics.

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