На сегодняшний день актуальным является скорейшее принятие Закона Украины «О государственном регулировании в сфере обеспечения электромагнитной совместимости технических средств и качества электрической энергии».

Список литературы: 1. *Уильямс, Т.* ЭМС для разработчиков продукции. – М.: Издательский Дом «Технологии», 2003. – 540 с. **2.** Directive 2004/108/EC of the European Parliament and of a Council of 15 December 2004 on the approximation of the laws of the Member States relating to electromagnetic compatibility and repealing Directive 89/336/EEC (Text with EEA relevance) // Official Journal of the European Union. – 31.12.2004. – L 390. – P. 24-37. **3.** Техническое регулирование: Теория и практика» / Под. ред. *В. Г. Версана.* – М.; ЗАО Издательство «Экономика», 2006. – 308 с. **4.** R & TTE Directive 99/5/EC of the European Parliament and of a Council of 9 March 1999 Radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity // Official Journal of the European Union – 07.04.1999. – L. 91. **5.** Про затвердження технічного регламенту з електромагнітної сумісності обладнання: постанова Кабінету Міністрів України від 29 липня 2009 р. № 785 // Офіційний вісник України. – 2009. – № 58. – 10 серпня. – С. 39. **6.** *Князев В. В., Лесной И. П.* Электромагнитная совместимость – новый обязательный аспект качества радиоэлектронной продукции // Сборник научных трудов 2-го Международного радиоэлектронного форума «Прикладная радиоэлектроника. Состояние и перспективы развития» (МРФ'2005). – Х.: [б. и.], 2005. – Т. 6. – С. 30-31. **7.** Про державне регулювання в сфері забезпечення електромагнітної сумісності технічних засобів та якості електричної енергії: [Проект Закону України]. – Режим доступу: http://www.rada.gov.ua:8080/pls/zweb_n/webproc34?id=&pf3511 =16865&pf35401=45624

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THE EMISSION CURRENT FROM DISSIPATION MEANS AND LIGHTNING ARRESTERS AS A QUALITY DATA

Розглянуто результати експериментальних досліджень характеристик струму імпульсної корони від пристроїв, які названо розсіювачами, та блискавкоприймачами різноманітних типів. Порівняння між струмом, який протікає скрізь шунт та напругою між плоскостями показує що реєструється струм заряду електричної ємності між плоскостями а не емісійний струм. Показано, що необхідно розглядати емісійний струм як струм стримерів, які добре видно на осцилограмах. Ефективність розсіювачів та блискавкоприймачів може визначатися за часом появи першого стримеру.

The experimental test results of impulse current characteristics from devices called dissipaters and lightning arresters (air terminals) of different types are considered. the correlation between current flowing through the shunt and voltage between the plates shows that the fixed curve refers to the charge current

of the capacitance between plates but not emission current. It is necessary to consider the emission current as the current of streamers that are explicitly visible on oscillogram. The time an dissipater devices and lightning arresters needs to generate the first streamer could reflect it's efficiency.

I Introduction

Principle of action of devices is based on the change of the insulation strength air gap between lightning protective devices (air terminals or dissipaters) and lightning leader. For an air terminal required declines, and for dissipaters required increase the breakdown voltage. One of physical phenomena which can influence on this process is an emission currant from protective devices. The degrees of correlation of parameters of emission current from dissipater devices and lightning arresters with protective properties of these devices are presented by considerable practical interest. The many scientists investigate this question. The most system researches are conducted by S.Grzybowski [1, 2] and F.D'Alessandro [3, 4]. Presently there are not normative documents which regulate requirements to dissipater devices. One of reasons is an insufficient volume of results, got in different proof-of-concept laboratories. In addition, results are got different researchers sometimes have opposite conclusions. For example in the [5] is there are such conclusions which for plenitude of exposition are quoted: «The study found that lighting air terminal (LAT) under condition with ionization have higher breakdown voltage compared to condition without ionization. It also found that the blunt configuration has the lowest breakdown voltage in both condition. This suggests that blunt rod is the best performance rod compared to other (standard, sharp, flat, conical and concave).» So, an author proposes that the modification of LAT geometrical tip could be an alternative for future application to protect buildings against direct strikes.

Contrariwise, in the [5] is there are such conclusions which are quoted, too: «The indoor test of sharp and blunt (tip with radius 12.5 mm) rod provides some evidence that this may be the case, since the ratio was reduced from 3:1 to 2:1 for a rod height change from 2.5 to 5.0 m. The sharp tip (conical tip with radius 0.2 mm) means this rod would be the first to produce corona streamers and, while the time might be too early to propagate a leader, this early activity is enough to quench activity from the adjacent rod and gain the slight advantage that is needed to break down the gap. Over the 10 m gap, this effect is nullified. The results of the tests where the rod-rod gap was 26 m give a superficial conclusion that geometry of the rod tip, corona emission and space charge have no effect on the strike probability, at least in «laboratory» test».

Reason of so different conclusions is based on erroneous interpretation of results in [5]. The investigation conduct by applying negative standard lighting impulse voltage (1.2/50 μs) from a 2 MV Marx Generator. If we look to the table 2 and table 4 (presented in [5]) we see, that time to breakdown for all samples about 10 μs. Therefore, breakdown of the gap have place on the droop of pulse voltage.

So the lower breakdown voltage correspond with greater time from the beginning of the process. As know [6], the quality of the LAT in inverse proportion to breakdown time. Therefore, quality of the LAT so much the better than it works quicker. Consequently, a blunt rod is worst from this point of view. Such conclusion is correct to air terminal under condition with ionization.

Degree of influence of the preliminary ionization of ambient space also have not hung jury. In [7] K. Feser note: «If the cathode of the spark-gap is irradiated by means of a quartz lamp (500 W, wave length 366 nm), it appears that breakdown probability distribution will not be influenced by irradiation. DC voltage preionization of the spark-gap will also show that breakdown probability is not dependent of the pre-stressing with dc voltage.» The results was take under actions of negative standard lighting impulse voltage (1.2/50 μs) for gap length from 1 to 15 cm. However, standard [6] requires realization of preliminary ionization of LAT under test.

In the reference [2] emission currant for the Franklin rod, TerraStat models TS100, TS400 and Spline Ball Ionazer was investigate. An emission current magnitude for the different variants of terms under the tests is in a range from 10 mA to 50 mA. However, it is known [3] that the emission current magnitude in analogical terms does not exceed 0.1 mA: «Corona currant for the Franklin rod (conical tip with radius 1 mm, length 2 m) in the electric field approximately 100 kV/m not more then 0.1 mA.»

To that end, we are conduct researches which partly repeat ones of Mississippi State University. Researches are conducted on analogical standards, on analogical method. For basis the conditions of tests, regulated by the Standard of France [6] are taken.

II Test equipment and samples

The test set up is described below. The pulse voltage generator: max-output voltage of 1.2 MV for both polarities. Voltage of the electrical field imitating the fields typical for storm activity was created by a flat electrode of rectangular form (4.3m x 4.8m). The characteristics of the field varied for waveforms of 1.2/50 μs and 0.1/5.0 ms. The height of electrode suspension varied in a range from 2 m to 4 m. Tests were carried out in two modes: with the supply of the permanent field with voltage from10 kV/m to 25 kV/m, and without it. Shunt resistance of 1kΩ. Oscilloscope TDS2024B and DPO4104 were used. Measurements of temperature, pressure, absolute and relative humidity do by the weather-station AMI-300. The general view of the test setup present on Fig.1.

Comparison of the parameters which realized under test in the R&D Institute «Molniya» with the requirements of the standard of France [6] shown in Table 1.

Researches were conducted on the following single samples of the lighting air terminal:

– TerraStreamer II Generation (3 samples), one of it show on Fig. 2, *a*;

– TerraStreamer ESE Terminal TSE 40 (Fig. 2, *b*);
– Competitor samples (CS-1).

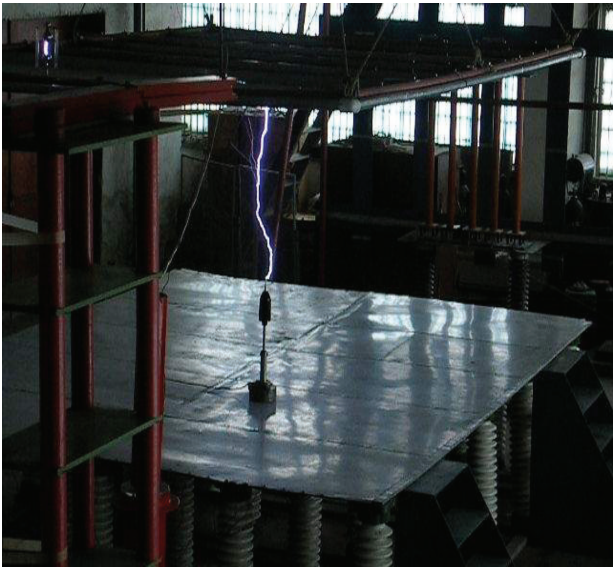

Figure 1 – General view of the test setup (air gap breakdown)

Researches were conducted on the following single samples of the dissipater which is analogical of ones describe in [2]:
– TS-100;
– TS-400 (Fig. 3);
– Competitor Samples (CS-2) Spline Ball Ionazer (Fig. 4).

Table 1 – Comparison of the parameters which realized under test in the R&D Institute «Molniya» with the requirements of the standard of France [6]

Parameter, dimension	Requirements of the standard [6]	Realized during researches
Electrostatic field intensity, kV/m	from 10 ÷ 25	25 ± 0.5
Voltage pulse rise time, µs	100 ÷ 1000	436 ± 5
Pulse rise rate, V/m/s	$2{\cdot}10^8 \div 2{\cdot}10^9$.	$(1.65{\cdot}\pm 0.08)\,10^9$
Distance between plates (H), m	≥2.0 m	2.0 + 0.01
Distance from the end of ESE to the upper plate (d), m	≥1.0 m	1.2 ± 0.01
d/H ratio	0.25 ÷ 0.5	0.4 ± 0.02
Dimensions of plates, m	≥2.0	4.0

a *b*

a – TerraStreamer II Generation; *b* – TerraStreamer ESE Terminal TSE 40

Figure 2– Samples of the lighting air terminal

Figure 3 – TS-400

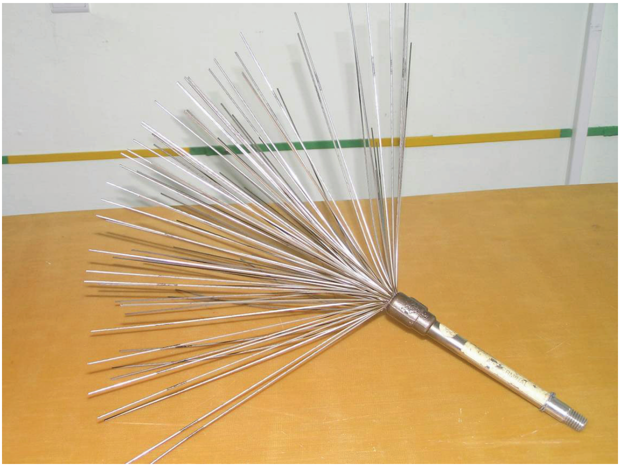
Figure 4 – Spline Ball Ionazer (CS-2)

III Results and discussion

Two types of tests are conducted: determination of breakdown time by the methods of standard [6] and measuring of emission current by the methods of Mississippi State University [2].

The tests of the lightning terminals were conducted with the value of rise time voltage pulse of 436 μs and pulse width (by level 0.5) of 1920 μs. The values of breakdown time for each device were determinate. By them the arithmetic average (T) was determined. Similarly, the arithmetic average of the breakdown time for the passive sharp-top lightning rod (FLR) was determined. These values of breakdown times were transferred to the basic curve of the standard [6], using which ΔT was determined for each device. The test results show in Table 2. These results justified the existence of some designs of ESE terminals statistically providing faster time of air gap breakdown, i.e. in fact decreasing the breakdown strength of this gap. In particular, the CS-1 has the best properties with regard to advance time (40 μs) among the submitted devices, while the ESE-40 and New 3 devices have properties comparable with those of the former.

However, there is one aspect not mentioned before which became evident when processing the test results. The matter concerns comparison histograms of the distribution of breakdown time of the ESE and sharp-top FLR as show on Fig. 5. The analysis of the histograms shows that for each device they considerably cross in practically important time interval. Taking into account the fact that lightning strikes an object rather rarely, is it possible to state that this single lightning will strike the lightning terminal with its mean value ΔT given in Table 2. Therefore it is necessary to create an ESE sample which will have a histogram adequately shifted to the left (in the direction of less time) so that no discharge in the passive sharp-pointed lightning rod could be in the range of this histogram.

Table 2 – Breakdown times

Sample	Average breakdown time, µs	Advance time ΔT, µs
ESE-40	225	38
New 1	235	15
New 2	238	8
New 3	222	36
CS-1	213	40
FLR	247	0
TS-100	235	15
TS-400	305	– 90
CS-2	271	– 32

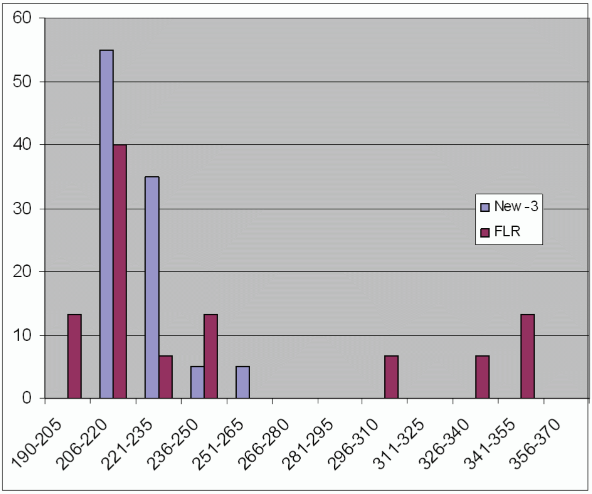

Figure 5 – Histograms of the distribution of breakdown time of the LAT (New-3) and Franklin lightning rod

The tests of the dissipater were conducted with the value of rise time voltage pulse of 436 µs and pulse width (50 %) of 1920 µs. The height of electrode suspension varied in a range from 2 m to 4 m. Shunt resistance of 1kΩ. The amplitude-time parameters of current flowing through a shunt are individual for each device and depend on the following process parameters: voltage on the potential electrode; distances between electrodes; distances from the upper point of the device to the upper electrode. The peak current values and integrated charge values for each of the devices given in Table 3 were obtained under the following conditions:

– voltage on the potential electrode – (560±10) kV;
– distances between electrodes – 2 m;
– distances from the upper point of the device to the upper electrode – 1.2 m.

Table 3 – Emission currant parameters

Sample	Emission current, I, mA	Charge, μC
ESE-40	11	2.7
New 1	12	3.0
New 2	10	2.5
New 3	10	2.5
CS-1	15	3.8
FLR	6	1.5
CS-2	26	6.5
TS-400	20	5.0
sphere 125 mm	12	3.0

For tensions, distant from breakdown values, a current has a smooth form of curve. During the researches, it was determined that the correlation between current flowing through the shunt and voltage between the plates shows that the fixed curve refers to the charge current of the capacitance between plates but not emission current. It was determined that for the tensions near to a breakdown current has surge, as shown on a Fig. 6. These current surge are conditioned streamers, which at certain condition will produce to breakdown of air gap. Finding out conformity to law of their origin is of interest.

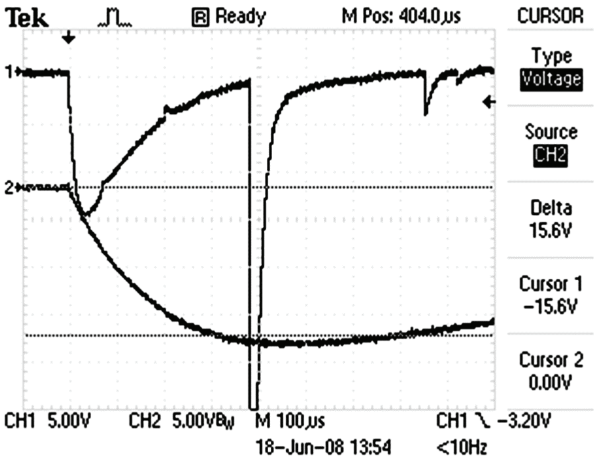

Figure 6 – Emission currant from investigate device (curve 1) and voltage between plates (curve 2)

IV Conclusion

Based on the results of the researches conducted the following conclusions can be made:

A) The study justified the existence of some designs of ESE terminals statistically providing faster time of air gap breakdown, i.e. in fact decreasing the breakdown strength of this gap.

B) The study justified that some designs called Dissipater provide an evident effect of air gap strengthening. In particular, the TS-400 device increases the time of air gap breakdown by 90 μs with respect to the breakdown time of the standard passive sharp-pointed lightning rod.

C) It is necessary to create an ESE sample which will have a histogram adequately shifted to the left (in the direction of less time) so that no discharge in the passive sharp-pointed lightning rod could be in the range of this histogram.

D) The interpretation of the results of emission current must be specified:
   - the apparent curve corresponds to the charge current of the capacity between the device and the upper plate;
   - the pulse corona current generated by streamers is fixed at voltages approaching to the breaking-down voltage. Therefore the measurement procedure needs to be changed to make it possible to perform measurements during possible air gap breakdown;
   - the main characteristic of the device is the time the first streamer appears having statistical straggling.

E) It is necessary to consider the emission current as the current of streamers that are explicitly visible on oscillogram. The time which needs for an dissipater devices and lightning arresters to generate the first streamer could reflect it's efficiency.

F) Authors suppose that on the basis of study of streamers it will be succeeded to create criteria for the certification of such devices

References: **1.** *S.Grzybowski, C. D.Taylor* Emission Current from Static Dissipater Devices Under Rain and Wind Conditions // Website of the 88th American Meteorological Society (AMS) Annual Meeting, Conference Code: 3LIGHTNING, Paper: P2.12. **2.** *S.Grzybowski, T.Disyadej, S.Mallick* Effectiveness of Lightning Protection Devices // 2008 International Conference on High Voltage Engineering and Application, Chongqing, Chine, Nov. 9-13. – PP. 49-52, 2008. **3.** *F.D'Alessandro, G.Berger* Laboratory studies of corona current emissions from Blunt, Sharp multipoint air terminals // J. Phys. D: Appl. Phys. 32. – PP. 2785–2790, 1999. **4.** *F.D'Alessandro, C.J.Kossmann, A.S.Gaivoronsky* Experimental Stadi of Lightning Rods Using Long Sparks in Air // IEEE Transactions on Dielectrics and Insulation. – Vol. 11, No. 4. – PP. 638–648, 2004. **5.** *L.M.Ong, H.Ahmad* Lightning Air Terminals Performance Under Conditions Without Ionization and With Ionization // plase of puplication. **6.** NF C 17-102: 1995. Lightning protection. Protection of structures and open areas against lightning using early streamer emission air terminals. **7.** *K.Feser* Influence of the Pre-Discharges on Breakdoun Behaviour of the Negative rod-Plane Spark-Gap at Standard 1.2/50 Impulse Voltage // Electrotechnik und Maschinenbau. – 88, Vol. 8. – PP. 347-352, 1971.

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