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Experimental Research of Pulse Processes in the Object Grounding System

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Introduction

The main requirement to the grounding system is to ensure the human and equipment safety against damage ant to provide the reduction in the level of disturbances , and also to provide the reference potential to the electronic, analogous and digital circuits. Intensive application of the microprocessor-based devices which are sensitive to the low-level disturbances increases the failure probability of the important systems of the object under the influence of various electromagnetic factors of natural and technogenic origin. Lightning is the most widespread source of electromagnetic disturbances of the natural type. When the lightning directly strikes the lightning-rod, the traveling surge wave propagates along the grounding system, and its frequency spectrum varies from tens of kilohertz to several megahertz. Highest amplitudes in the lightning radiation spectrum emerge in the frequency range of 300 - 20 000 Hz [1].

Electromagnetic impacts can be investigated both in the time and frequency domains. Occasional pulse processes can be transformed from the time domain to frequency domain using Fourier integral, and periodic processes – using Fourier series [2]. However in most cases not only the precise description of the disturbance pulse shape, but also precise parameters on which the disturbing impact is dependent, are important.

Evaluation of the pulse processes is important when pulses affect the secondary circuits of the object (measurement, control, automation, etc.) and permit the estimation of the efficiency of the offered protection norms and to engineer the more reliable protection [3].

Existing approach to the implementation of the grounding of technical systems

In general case the two parts of the object grounding system can be distinguished: external and internal. External protective grounding is required to provide a low ohm contact with the „ground“ in most cases. Protective grounding network situated inside of the building is created of the separate conductors connected in a particular order one with another. The resistance of these conductors is relatively low in the low-frequency range and they conduct the electric current very well. In the higher frequency range the wave resistance increases and the separate conductors behave similarly to the inductive coils. In the higher frequency range the electric contact to the „ground“ practically disappears. Parasitic capacitive resistance decreases, but the inductive grounding resistances increase. Therefore the protective grounding does not qualify to be the reliable lead-off of the electromagnetic pulse.

As it is stated in [4], in the frequencies which satisfy the inequality $l > \lambda/8$ (λ – the length of the wave), the resistance between two grounding points may become significant ant the implementation of the equipotential points becomes complicated. The voltage induced by the electromagnetic pulse between the devices of technical systems and the „ground“

$$U_{st} = R \cdot \Delta i + L \cdot \frac{\Delta i}{\Delta t}, \qquad (1)$$

here R and L – the resistance and inductance of the connecting lines and the grounding electrodes respectively;

$\Delta i/\Delta t$ – the rate of current alteration in the contour, which is implemented using the frame and conductors which connect it to the ground.

Since the current pulse front can be steep, therefore the voltage conditioned by the parameter $L\,\Delta i/\Delta t$ is significant to magnitude U_{st}. Active component of the disturbance voltage $R\,\Delta i$ remains relatively small, when the cross section are selected rationally enough (conductor must be as short as possible, and the cross-section – as large as possible). The inductance of the line with cylinder-shaped conductors

$$L = l\cdot\left(\frac{\mu_0}{\pi}\right)\cdot\ln\left(\frac{2d}{D}\right), \qquad (2)$$

and inductance in case of the line with the planar adjacently placed rectangular-shaped cross-section conductors

$$L = l\cdot\left(\frac{2\mu_0}{\pi}\right)\cdot\ln\left(1+\frac{1}{1+\frac{a}{b}}\right). \qquad (3)$$

It follows from the presented equations that in order to decrease the inductance L the following methods can be used: shortening of the line length, decreasing of the distance between conductors of the round-shaped cross-section to the minimum, and in case of the rectangular-shaped cross-section conductors – increasing of the ratio a/b.

The grounding system creation principles

At the present time non-insulated lightning-rods are used to provide the external protection from the lightning. Separate grounding device is usually installed for them which is also connected to the main grounding contour of the building. When implementing the grounding inside of the buildings in which microprocessor-based management and control devices are used the closed-type grounding system is used. Insulated grounding systems usually are not used to protect the electronic equipment. During the lightning strike or when some breakdown occurs in the electric supply systems undesirable transient voltages emerge between the insulated grounding system and the parts of the device. Furthermore the attempt to separate the grounding systems is usually futile, since the grounding conductors may have many random contacts.

At the present time there exist two diametrically opposite approaches to the grounding of the microprocessor-based equipment of the management and control systems (MCS). According to the first approach the MCS equipment closets are grounded using radial scheme. This means that all protective insulated conductors, meant to ground this equipment, are connected to the common bus and are grounded at one point. For this reason the equal potential of the grounding conductors is obtained and no closed-loops are formed in their circuits. Other approach involves the connection of the separate MCS closets to the common grounding device using protective conductors, without connecting them at the same point. The potential equalization is also achieved when using such multiple grounding [5]. Conductive holders of the cable lines are grounded from both ends and at their intersections with other metal elements.

Characterization of the surge registration scheme

Experimental equipment [6] consists of the lightning pulse imitating device, oscilloscope to register the process and the model of the grounding system (Fig. 1).

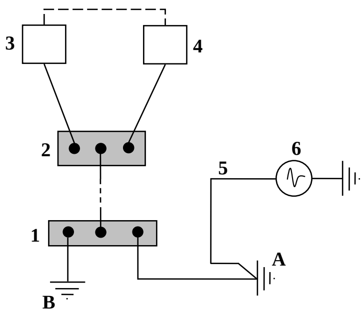
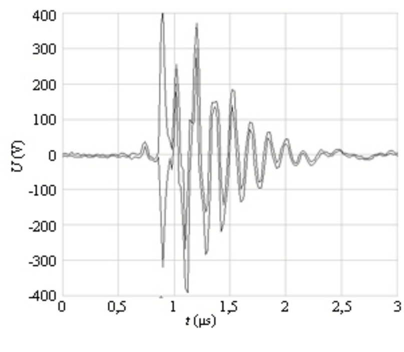


Fig. 1. The model of the investigated grounding system: A – the lightning protection grounding device ($R_g = 30\ \Omega$); B – the building grounding contour ($R_g = 0{,}33\ \Omega$); 1 – the main equipotential bonding bar; 2 – the intermediate earthing reference point; 3, 4 – frames of closets (panels); 5 – the down conductor; 6 – the lightning pulse imitating device

The lightning pulse imitating device was connected to the building lightning receiver and additional electrode placed on the ground approximately 20 m away from the building. Tests were carried out using pulse similar to the rectangular wave; the pulse amplitude reached 28 kV. Internal grounding system consisted of the insulated copper conductors and equipotential bonding bars 1 and 2. Lengths of the grounding system conductors were: $L_{12} = 9.5$ m; $L_{23} = 10$ m; $L_{24} = 13$ m; $L_{34} = 2.5$ m; $L_5 = 11$ m; $L_{1B} = 3.5$ m. The closets 3 and 4 had the zero conductors disconnected and they were grounded only from the intermediate earthing reference point 2.

Registration of pulses and the analysis of the obtained results

During the experiments the disturbances were registered using the oscilloscope FLUKE-199 with the memory capacity of 27500 points. The measurement results are illustrated in Fig. 2 – Fig. 4.



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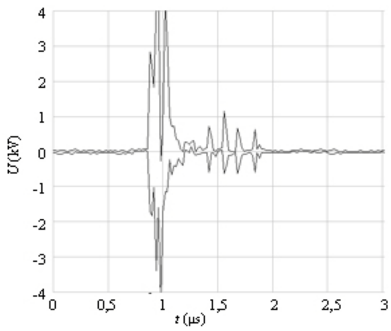

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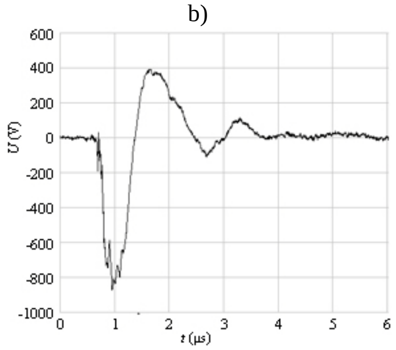
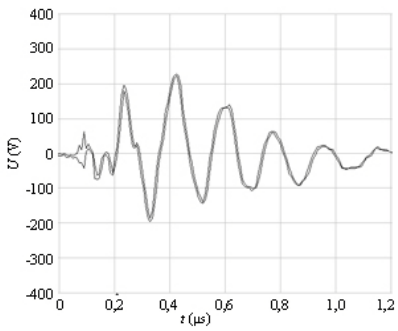


c)

Fig. 2. Oscillograms of the test pulses induced by the transient process at the first point (main rod) under different grounding resistances: a – the transient process at the wavefront of the disturbance, when R_E = 30 Ω; b – the transient process, when the lightning protection and building grounding devices are connected, $R_E \approx 0.03$ Ω; c – general shape of the disturbance, R_E = 0.33 Ω

As it can be seen from the oscillograms, the tests pulse at the electrical inlet of the building and at some other characteristic points of the internal grounding system 2, 3 and 4 was transformed to periodic fading oscillations. This can be conditioned by various reasons, and the main of them – the resistances of the grounding conductor and grounding device. When the resistance of the grounding device varies from 0.33 Ω to 3 Ω (Fig. 2 – Fig. 4, cases a and c), the duration of the transient process decreases when transiting from to point 1 to the point 3, and no obvious change can be observed under the very small resistance of the grounding device (R_g = 0.033 Ω). The potential variation along the building grounding system is discontinuous during the transient process. The character of its change can not be related only to the values of the resistances of the grounding device.



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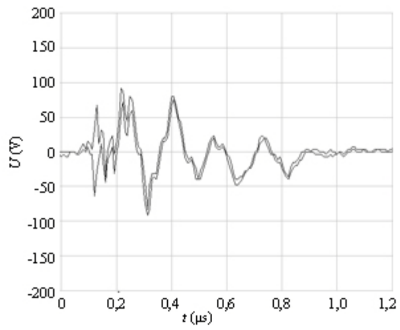

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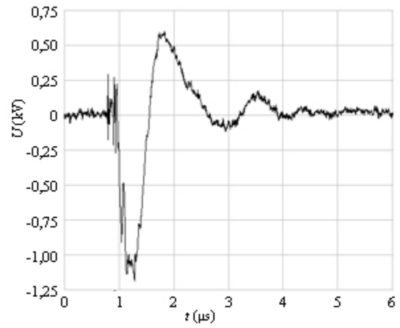
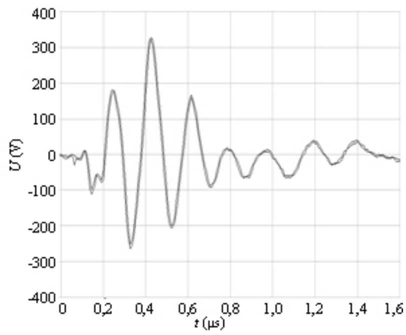


c)

Fig. 3. Oscillogram of the transient process at the second point: a – the transient process at the wavefront of the disturbance, when R_E = 30 Ω; b – the transient process, when the lightning protection and building grounding devices are connected, $R_E \approx 0.03$ Ω; c – general shape of the disturbance, R_E = 0.33 Ω

For example, in Fig. 2 – Fig. 4, in the case a the highest potential varies as: first point – 408 V, second point – 228 V, third point – 328 V, i. e. potential decreases when transiting from the first point to the second and later increases again. High electrical potentials can be obtained not only at the wavefront of the transient process, but at the other locations also, approximately at the middle or even at the second part of the transient process. This fact can be easily seen from the oscillograms in Fig. 2 – Fig. 4, case c.

If the grounding conductors are close to each other, the inductive resistances of the grounding circuit grow considerably and the role of the capacitive and inductive coupling between the grounding circuits increases. The grounding conductors start generating the pulse magnetic field. As it is stated in the earlier research [1], the strength of such field may exceed 1 kA/m inside of the room even when the lightning current carrying conductor itself is placed far away.



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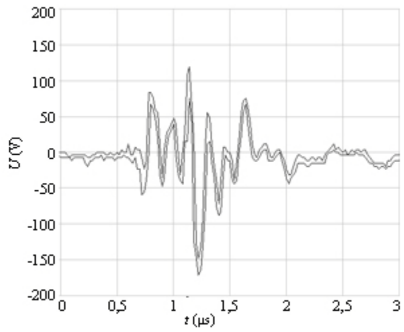

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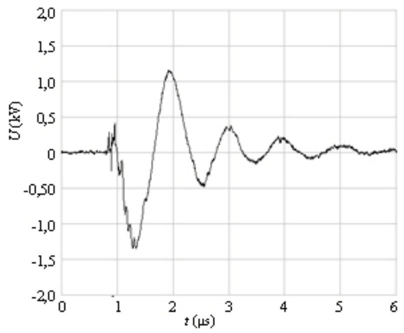

c)

Fig. 4. Oscillogram of the transient process at the third point: a – the transient process at the wavefront of the disturbance, when R_E = 30 Ω; b – the transient process when the lightning protection and building grounding devices are connected, R_E ≈ 0.03 Ω; c – general shape of the disturbance, R_E = 0.33 Ω

Conclusions

With the aim to determine the highest potential in the grounding system it is necessary to observe and register not only the pulse wavefront of the disturbance but its general alteration character also.

The electrical potential carried into the building through the grounding system is mostly influenced by the initial potential of the lightning wave, wave resistance of the grounding device and the number of the wave reflection points.

When analyzing the questions of the electromagnetic compatibility, it is not always enough to consider such concepts as resistance and potential. Besides these parameters it is also necessary to evaluate the non-equipotential state of the separate points of the grounding system and the magnetic fields induced by the currents flowing through the grounding system of the equipment. Electromagnetic field magnitudes in the objects can exceed the allowable critical equipment parameter values due to the lightning discharges. One of the main reasons – breakdowns of the grounding devices or incorrectly selected topology of the grounding circuits.

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The suitable grounding of sensitive electronic equipment cases in the building objects is one of the measures to reduce the effect of the disturbances which arise due to the lightning impact or various commutations in the power supply network. The data registration and analysis is essential when characterizing such disturbances. Registration demonstrates the real statistical parameters in the particular objects. In this work the influence of the object grounding system on the disturbances induced by the lightning discharge is evaluated. Ill. 4, bibl. 6 (in English; abstracts in English and Lithuanian).

N. Bagdanavičius, A. Drabatiukas, Š. Kilius, J. Daunoras. Impulsinių procesų objekto įžeminimo sistemoje eksperimentinis tyrimas // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2010. – Nr. 10(106). – P. 47–50.

Viena trikdžių, kurie dažniausiai atsiranda dėl žaibo poveikio arba įvairių komutacijų maitinimo tinkle, poveikio mažinimo priemonių yra tinkamas jautrių elektroninių įrenginių statiniuose korpusų įžeminimas. Apibūdinant trikdžius, pagrindas yra duomenų registravimas ir jų analizė. Registravimas parodo realius statistinius parametrus konkrečiame objekte. Šiame darbe nagrinėjama objekto įžeminimo sistemos įtaka žaibo išlydžio sukeltiems trikdžiams. Il. 4, bibl. 6 (anglų kalba; santraukos anglų ir lietuvių k.).