SIMULATION OF SURGE PROTECTION ACCORDING IEC 61000-4-5

МОДЕЛИРОВАНИЕ МИКРОСЕКУНДНЫХ ИМПУЛЬСНЫХ ПОМЕХ СОГЛАСНО МЕЖДУНАРОДНОГО СТАНДАРТА МЭК 61000-4-5

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Abstract: *An important requirement of digital electronic devices is the comprehensive provision of electromagnetic compatibility. In particular, it is necessary for electrical, electronic and radio equipment to ensure a sufficient level of noise immunity when exposed to microsecond pulse interference. The international standard IEC 61000-4-5 regulates the testing of equipment for microsecond impulse noise. Carrying out such physical tests is quite complicated and requires expensive equipment. The article proposes computer simulation of testing electronic devices in accordance with the requirements of IEC 61000-4-5.*
***KEYWORDS**: ELECTROMAGNETIC COMPATIBILITY, MICROSECOND PULSED NOISE, MODELING, NOISE EMISSION, NOISE IMMUNITY.*

1. Introduction

Electronic equipment operating in an industrial environment is subject to rather stringent requirements, including the field of electromagnetic compatibility. To meet these requirements, the international standard IEC 61000-4-5 is used, which sets up noise immunity criteria and test procedures related to voltage and current emissions [1].

The standard describes two methods of applying a discharge [2]:

– contact discharge. As the name implies, in this case, the discharge tip of the generator directly contacts the device;

– air discharge. In this discharge, there is no direct contact between the tip of the discharge probe and the device. Instead, the dipstick is gently lifted to the unit until an air discharge occurs. This approach applies when the contact discharge method cannot be used for any reason.

However, such physical tests are quite complex and require expensive equipment [3]. Therefore, the article proposes computer simulation of testing electronic devices in accordance with the requirements of IEC 61000-4-5.

2. The reasons occurrence electromagnetic interference

In real conditions, a large number of different types of electromagnetic interference operate at the location of the electrical equipment (Fig. 1) [4]:

– short circuits;
– lightning discharges;
– transients during switching of power equipment;
– power network failures and distortions;
– electromagnetic fields caused by other equipment.

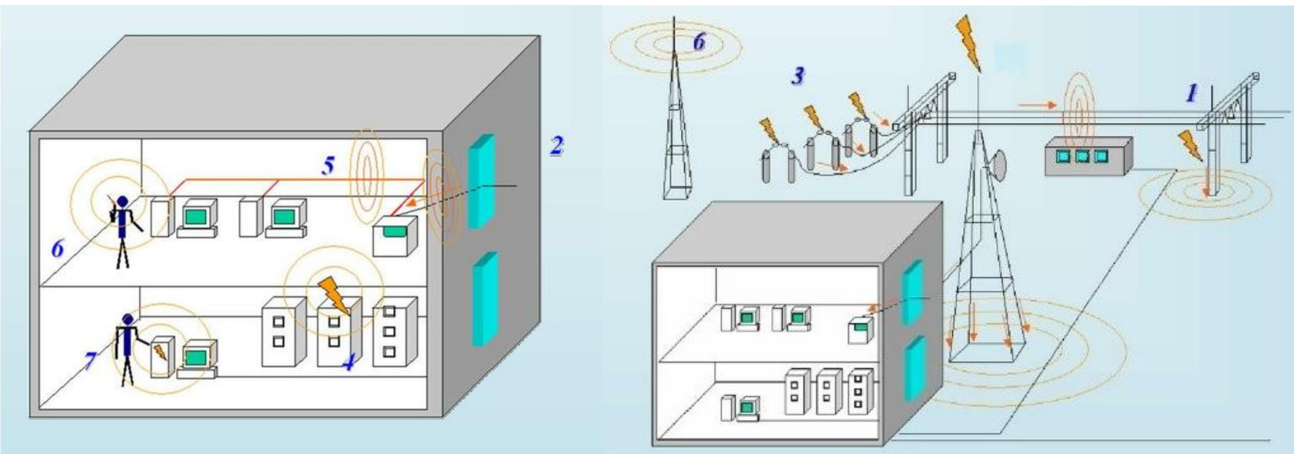


Fig. 1. *Sources of electromagnetic interference at power stations and substations:*
1 – short circuits; 2 – lightning discharges; 3 – transient modes of operation of high-voltage equipment; 4 – switching of electromechanical devices of various purpose; 5 – full-time operation of power electrical equipment (up to and above 1 kV); 6 – radio means; 7 – electrostatic discharge

In this case, industrial devices must function with specified quality criteria in the conditions of interference [5, 6].

3. The international standard IEC 61000-4-5

The international standard IEC 61000-4-5 applies to electrical, electronic and radio electronic devices and equipment and sets requirements and test methods for technical equipment (TE) data for resistance to high-voltage microsecond pulse interference (MPI) caused by overvoltages, switching transients and lightning discharges [7, 8].

Switching transients can be divided into groups related to:

– switching in powerful power systems, such as switching of capacitor batteries;

– switching in low-power power supply systems in the immediate vicinity of the vehicle or with changes in load in the electrical distribution systems;

– resonant voltage fluctuations in electrical networks caused by the operation of such switching devices as thyristors;

– damage to systems such as short circuits to ground and arc discharges in electrical installations.

The processes of formation of MPI at lightning discharges are basically reduced to the following [9]:

– upon direct lightning strike into the outer (outside the building) circle, the MPI voltage is formed due to the flow of a large discharge current through the outer and ground circuits;

– by indirect lightning strike (inside a cloud, between clouds or near objects), electromagnetic fields are formed that induce voltages or currents in the conductors of external or internal circuits;

– when lightning strikes the ground, the discharge current flowing through the earth can create a potential difference in the grounding system of TE.

Rapid changes in voltage or current when the protective devices are triggered can also lead to the formation of MPIs in internal circuits [10].

4. Pulse overvoltages from lightning

Lightning is one of the most powerful sources of electromagnetic interference (Fig. 2). This paper deals with the modeling of the effects of overvoltages resulting from indirect blow lightning.

Fig. 2. *Phenomenon occurrence lightning*

The duration of the lightning current pulse is mainly determined by the time of propagation of the reverse discharge from the earth to the cloud and ranges from 20 to 100 µs. The average pulse duration of a lightning current is close to 50 µs, which determined the choice of a standard voltage signal used for testing electrical equipment - a microsecond interference (Fig. 3) [11].

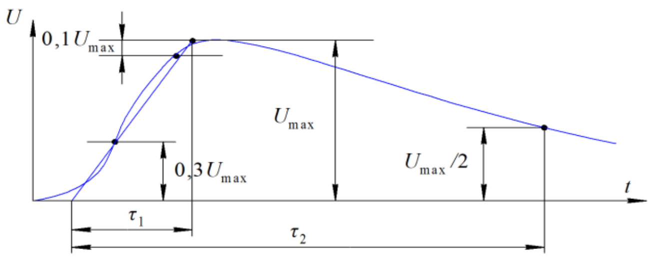


Fig. 3. *Lightning impulse parameters*

5. Equivalent microsecond pulse generator according to IEC 61000-4-5

International standard IEC 61000-4-5 describes the circuit diagram of a generator microsecond pulse obstacles (MPO) is shown in Fig. 4 [12].

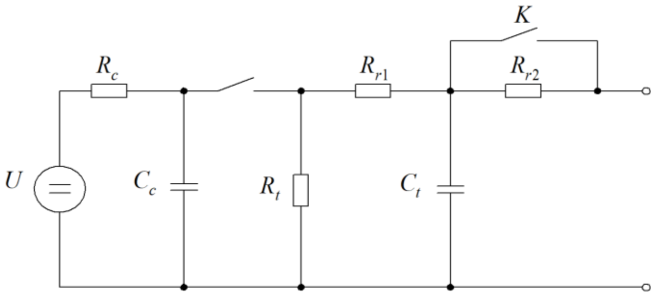


Fig. 4. *The circuit diagram of a generator MPO*

On Fig. 4 introduces the following designations: U is a high voltage source; R_c is a charge resistor; C_c is a charging capacitor (20 µF); R_t is a resistor that determines the pulse duration (50 Ohms); R_{r1}, R_{r2} are resistors that determine the output impedance of the generator (R_{r1} = 15 Ohms, R_{r2} = 25 Ohms); C_t is a capacitor that determines the duration of the impulse front (0.2 µF); K is a switch that is locked when using an external matching resistor.

Connection diagram of a generator MPO to the test device and the network is shown in Fig. 5 [13].

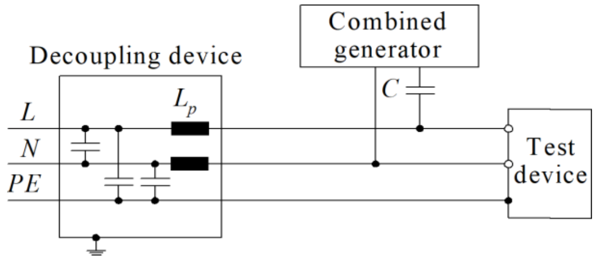


Fig. 5. *Connection diagram of a generator MPO*

6. The results of the physical experiment

Test results shall be classified on the basis of the following performance criteria, unless otherwise specified in the standards for the specific type of TE or in the technical documentation for the TE:

– criterion A. Normal functioning according to established requirements;

– criterion B. Temporary deterioration of the quality of functioning or termination of the performed function with the subsequent restoration of normal functioning, carried out without the intervention of the operator;

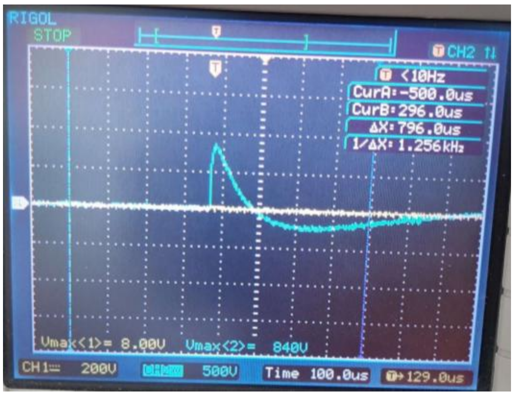
– criterion C. Temporary deterioration of the quality of functioning or termination of the installed function, requiring operator intervention or system restart;

– criterion D. Deterioration of the quality of operation or termination of the installed function, which are not subject to restoration by the operator due to damage to the equipment (components), software breach or data loss.

The test equipment must not become dangerous or unreliable as a result of interference with species regulated by IEC 61000-4-5 [14].

The results of a physical experiment, namely, waveforms of voltages at a resistive load of 1 kOhm when exposed to microsecond pulse noise from a generator of type IIP-4000 when applying different pulse amplitudes are shown in Fig. 6.

a



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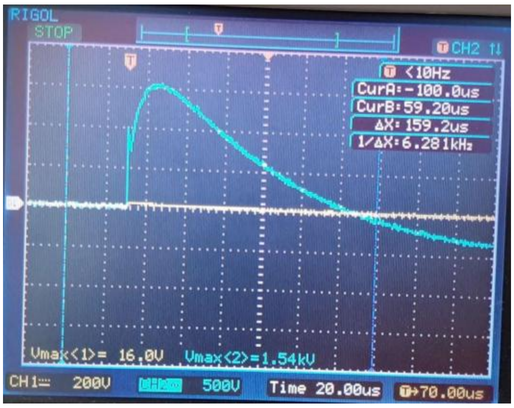

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Fig. 6. *Waveforms of microsecond pulses at a resistive load of 1 kOhm:*
a – 500 V; b – 1 kV; c – 2 kV

7. Simulation model of the microsecond pulse generator in Multisim program

To simulate the impact of microsecond pulse interference on electronic devices, the NI Multisim program has assembled an interference generator model, is shown in Fig. 7.

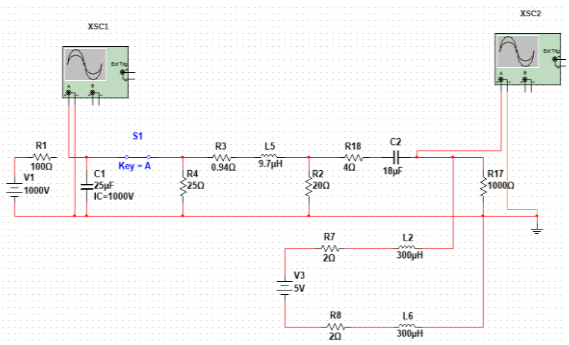
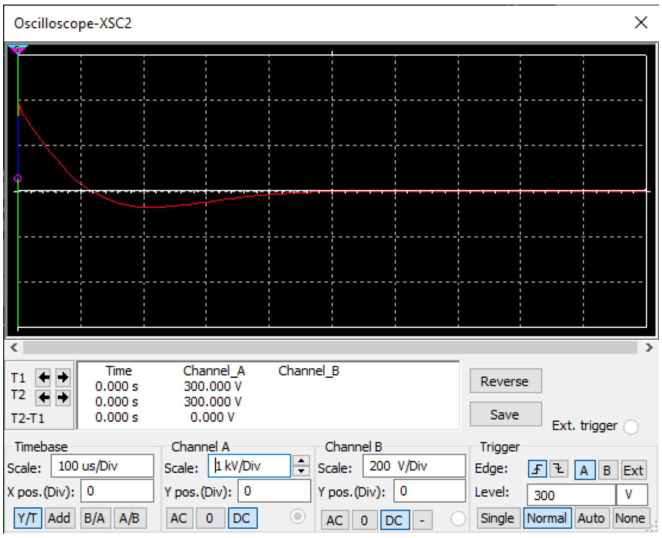


Fig. 7. *Model of microsecond pulse generator interference*

The dimensions of the model components were set in accordance with the recommendations of IEC 61000-4-5. The results of modeling the influence of microsecond pulse interference on the resistance of 1 kOhm are shown in Fig. 8.



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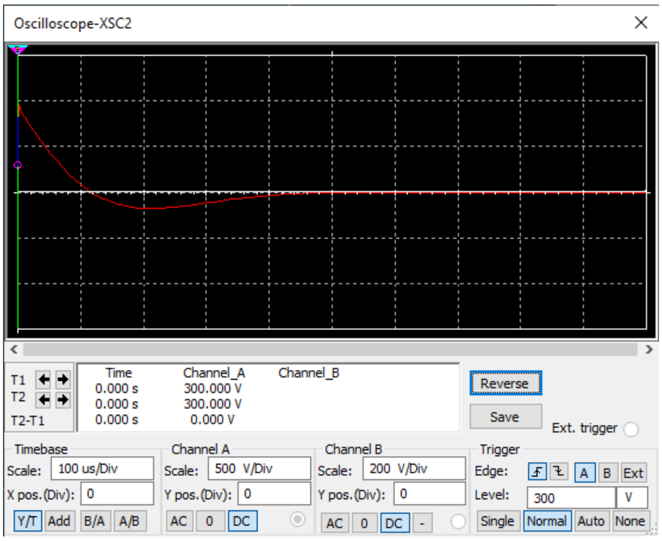

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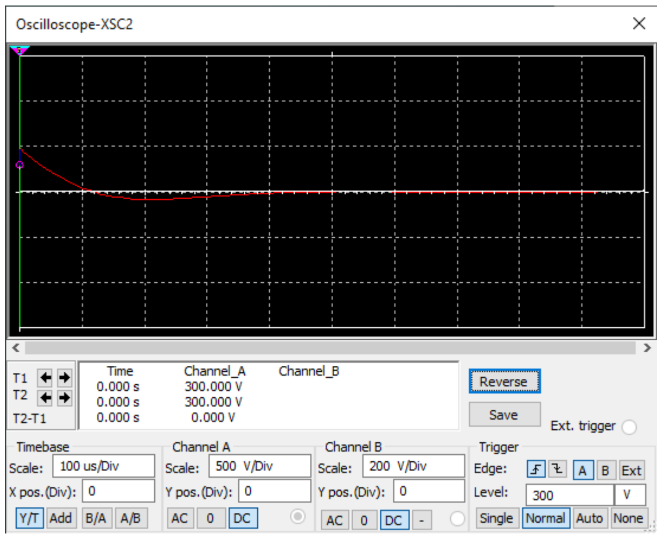

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Fig. 8. *Form of microsecond pulse interference generated by a virtual generator on a support of 1 kOhm:*
a – 500 V; b – 1 kV; c – 2 kV

To protect electronic equipment against the effects of microsecond pulse interference some recommended schemes are provided (Fig. 9).

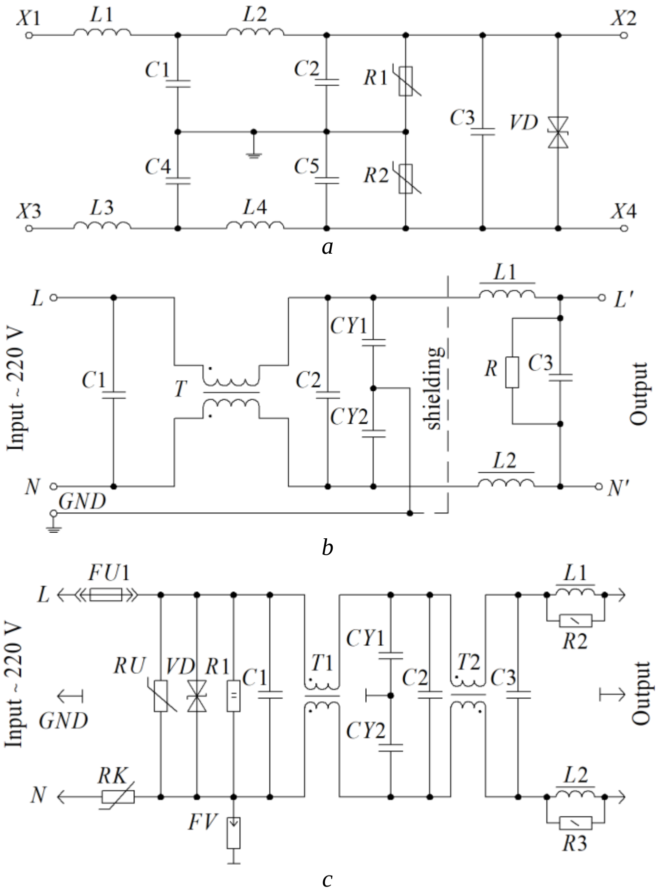

Fig. 9. *Possible schemes to protect electronic equipment from microsecond pulse interference:*
a – fifth-order filter with a bi-directional TVS diode and varistors; b – fifth-order filter with a common-mode choke; c – fifth-order filter with a bi-directional TVS diode, common-mode choke, varistors and fuses

To evaluate the impact of the effectiveness of the application of a filter rational use of modeling.

8. Results and discussion

The article presents the results of the study of the international standard IEC 61000-4-5, which regulates the requirements for test equipment, which simulates the impact of pulse overvoltage in electrical networks to electronic devices. The description of the causes of electromagnetic interference, an equivalent circuit of the interference generator and the required pulse shape are presented.

The developed models generate a test pulse shape that meets the requirements of the standard. The presented schemes allow to protect industrial devices from pulse overvoltages.

9. Conclusion

The developed simulation model allows for virtual testing of various electronic circuits for microsecond pulse interference, which will reveal the disadvantages of circuitry solutions of industrial devices at the stage of development. Accordingly, this will reduce the timeframe and additional costs of developing industrial appliances.

Computer simulation of testing electronic devices is carried out in accordance with the requirements of IEC 61000-4-5. Such physical tests are simple enough and do not require expensive equipment.

10. References

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