Means for measuring control of impulsive overvoltage caused by thunderstorms)

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***Abstract*—The analysis of national normative and technical requirements of the lightning protection systems shows the necessity of additional protecting measures from the direct strike of lightning or voltage induction by a remote discharge by determining protective devices choice and charts of their settings. The protection of information and communication systems and their electronic devices components is particularly dependent on the thunderstorms in the environment. Methods of calculation and protecting schemes from impulsive overvoltage recommended by international standards of IEC, are more hard and reliable.**

Therefore, it is proposed to apply in the circuits of protection against impulse overvoltage means of measurements. The proposed means for measuring control detects and fixes impulse deviations from sinusoidal form of network voltage. On this basis the application schemes of control devices for impulsive overvoltage are complemented, that substantially reduces the risk of fires and electronic device damage from thunderstorm origin. Implementation in the field of operation and maintenance of electronic and telecommunication equipment is proposed.

Keywords—impulse; measurement; amplitude; duration; overvoltage; lightning protection; electronic devices; hazard; damage

I. Introduction

For modern electronic and electrical equipment it is important to ensure its stable supply in accordance with the requirements [1-4] regarding the voltage of the electrical network. The reliability and efficient operation of this equipment depends to a large extent on the rapid changes in the shape of the industrial frequency voltage, which manifests itself as fast impulse distortions of the sinusoidal voltage of the network.

Their damage occurs due to the electromagnetic impulse of lightning - the electromagnetic effects of the lightning current, which are accompanied by both transient wave processes and the effects of the radiates electromagnetic field. In addition, the main thing is impulses surge voltage - transitional wave process caused by electromagnetic impulse of lightning, which appears by overvoltage and / or supercurrent in the conducting parts.

There are protective measures and devices for power supply and computer networks [2]. In addition, there is a need for measuring information about overvoltage induction parameters. When substantiating the installation of an internal lightning protection system, the cost of failure of the electrical equipment, the consequences of failures in its operation and the cost of data loss and information on such equipment must be taken into account.

II. State of Things

A. Analysis of the method of calculation of current spreading

The calculated values of lightning amplitudes and switching voltage impulses at the points of general purpose electric network connection for phase nominal voltages according to domestic and foreign normative documents [5] are given in Table 1.

TABLE I. THE VALUE OF IMPULSE AMPLITUDE VOLTAGE (KV) ELECTRIC GRID POINTS

Location of connection points	**Nominal voltage of the network, kV**								
	0.38	***6***	***10***	***35***	***110***	***220***	***330***	***500***	***750***
Air line	10	100	125	325	800	1580	1890	2730	3570
	6/10	160 2000	190 2000	575 2000	1200 2000	2400 -	3000 -	3200 -	4800 -
Cable line	6	100	125	325	800	1580	-	-	-
	6	34	48	140	350	660	-	-	-
Power transformer	-	60	80	200	480	750	1050	1550	1950
	-	34	48	140	350	660	-	-	-

To determine the distribution of currents between the metal elements of the building structure when lightning

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enters the system of external lightning protection, it is necessary to calculate the resistance of grounding devices, pipelines, power supply, communication cables, etc. In cases where it is difficult to make a precise calculation, a so-called qualified assessment is carried out on the basis of the following considerations:

- 50% of total current I_{imp} = 200kA (10/350) - I_{S1} = 100kA (10/350) is discharged through the grounding device of the LPS;
- 50% of the total current I_{imp} = 200kA (10/350) - I_{S2} = 100kA (10/350) is evenly divided (about 17%) between the external inputs into the object of the three main types of communications: communication and transmission cables, metal pipelines and cables/wires for power supply 220/380 V.

It is a classic example of the current distribution of direct lightning strike at a facility.

The value of the current passing through the separate input is denoted by I_i, while n is the number of inputs:

$$I_i=I_{s2}/n \,. \qquad (1)$$

To evaluate the current I_V in separate cores of the unshielded cable, the current in the cable is divided by the number of wires m: $I_V = I_i/m$.

For contact clamps and surge protective devices (SPD) current parameters are evaluated in each case individually. The maximum pulse overvoltage at the boundary of each zone is coordinated with the permissible voltage of the internal system. The SPD at different zones is also coordinated by energy performance. Class I SPD based on the arrester have $\boldsymbol{U_p}$ = 4 kV, on the basis of varistor even lower; Class II SPD have $\boldsymbol{U_p}$ = 1.3 - 2.5 kV; Class III have $\boldsymbol{U_p}$ = 0.8 - 1.5 kV.

Proceeding from the requirements of insulation impulse resistance coordination in power plants and the stability of the equipment to damage, it is necessary to choose the level of the SPD at a voltage lower than the maximum value, so that the effect on the equipment will always be below the permissible voltage. If the level of damage resistance is unknown, an indicative or test level should be used. In this case, it is expedient to use a measuring instrument for determining and controlling the level of impulse overvoltage.

B. Maintain Assumption

The reasons for the appearance of individual impulses or a series of them may be either switching processes or emergency situations in the power supply system, as well as certain unpredictable processes on the side of electricity consumers. For both sites, they can be driven by lightning discharges. They can be caused, for example, by radiation of conductive electromagnetic interference from individual objects or from atmospheric processes.

According to the regulatory requirements and the works of leading specialists [1, 6-9], impulse distortions of the network voltage are characterized by the following basic parameters of the electric power: the amplitude U_{mi} and duration of a single impulse t_i or a series of single- or bipolar impulses $t_{i\Sigma}$ of a diverse form.

Any voltage impulse can be represented in the form

$$u(t)=U_{mi}\cdot\varepsilon(t), \qquad (2)$$

where U_{mi} - amplitude and $\varepsilon(t)$ - is a normalized function that describes the shape of the investigated impulse. At the same time, Table 1 summarizes the most common types of fronts (recessions) of impulse signals.

Since the expression of the voltage signal distorted by impulse $f_U(t)$ can be regarded as the sum of the industrial frequency sinusoid functions and (2), then when realizing the means of measuring these parameters of electricity, a characteristic feature of the appearance and flow of such distortions is used. It consists in increasing the velocity of the temporal change of the distorted signal $s_U(t)$ in comparison with the sinusoid [10].

III. PROPOZED MEANS

To construct measuring instruments with high metrological characteristics for dynamic parameters of impulse disturbances in power grids it is expedient to use the principle of optimal distribution of measurement and control functions between elements of the measuring structure.

The structure of the developed instrument for controlling impulse disturbances dynamic parameters in power grids, which contains two parts: analog AU and calculating CU units [11] in fig. 1 shows.

AU consists of: NIDS – normalizing input device with software control, AS – analog switch, AD – amplitude detector, DID – block of detecting impulse distortions $f_U(t)$, RVS – reference voltage sources and ADC – analog-digital conversion unit.

CU consists of: SCM – single-chip microcontroller, RAM – operative storage device and OB - output buffer.

In general, the controlled signals of three phase voltages U_A, U_B, U_C after scaling in the NIDS are alternately in time transmitted through the AS to the DID input, the main element of which is the differentiator.

At the moment of the voltage impulse distortion DID stimulates the start of the monitoring program in the SKM and measures this phenomenon of electric energy quality deterioration - the emergence of impulses imposed on the low-frequency voltage signal of the industrial network.

In this case, the location of the momentum or series of pulses in one or another half of the repetition period of the sinusoidal voltage is fixed, as well as the cyclic work of the ADC is initiated and the bipolar AD is activated.

The ADC is a circuit with an independently controlled range of input signals $f_U(t)$, which outputs a code signal of optimal bit, regardless of the presence or absence of impulse distortion.

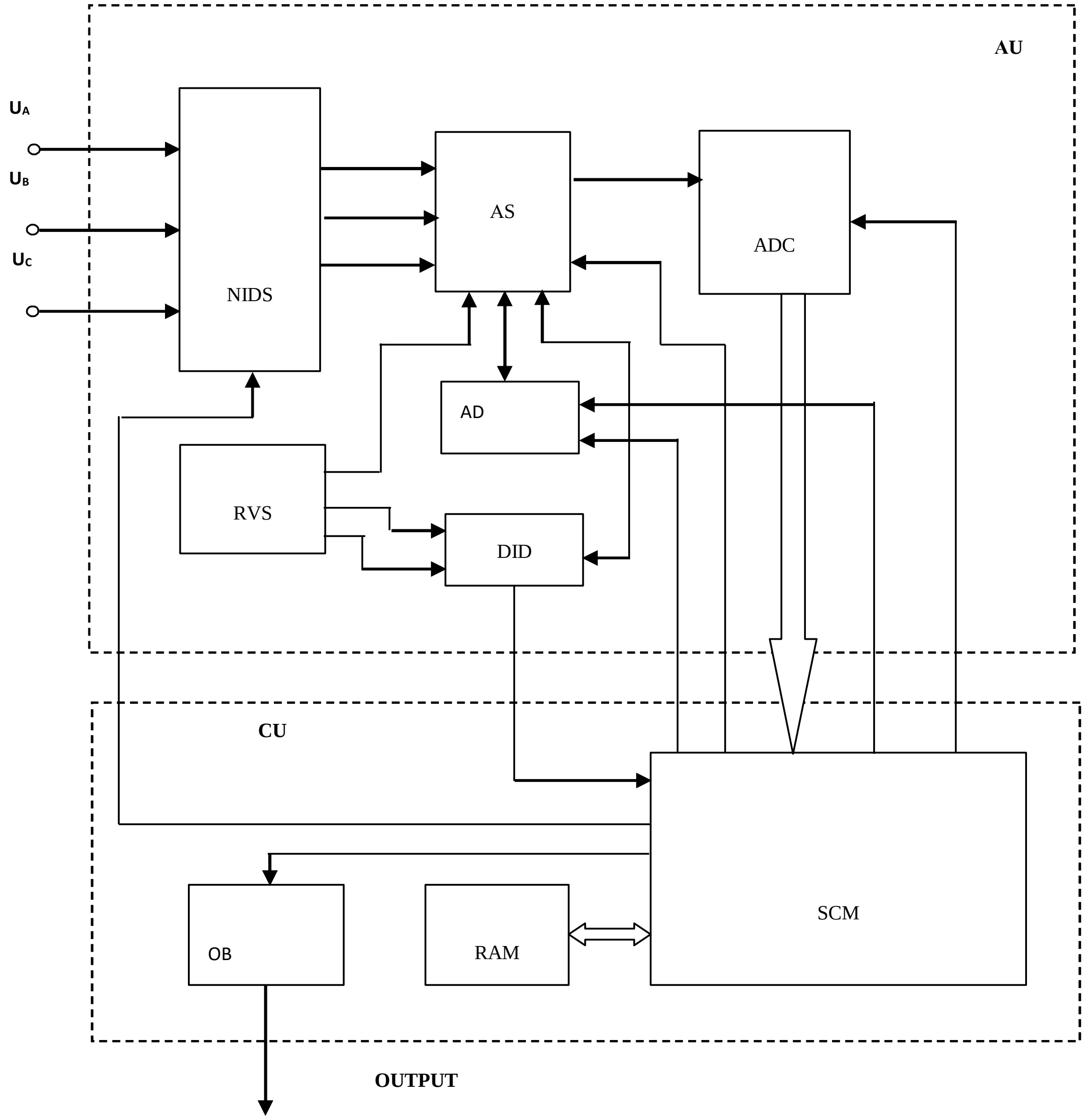

Fig. 1. Structure means of impulse disturbances dynamic parameters measurement in electrical networks

ADCs receives arrays of instantaneous values of phase voltages that are written to the RAM using the SKM. At the same time, the SKM program searches for a time interval t_{ia} that contains the values U_{mi} of a single or each of the a-th detected impulses. In addition, measurements of impulse duration t_i or series $t_{i\Sigma}$ are performed.

A specific feature of the developed measurement device is to obtain, as a result of finding and controlling the impulse voltage of two arrays of codes - the digital instantaneous values $\{u_i(k)\}$ of the impulse part of the investigated function $f_U(t)$ and their corresponding time values $\{t_{iU}(k)\}$. Thanks to the analysis of these arrays, the start and end of the detected $\{l_i\}$ impulses that constitute distortion $u_i(t)$ are recorded.

For each l_i impulse, the start $(t_{ni})_{li}$ and end $(t_{зi})_{li}$ times are fixed in the SCM, which are used to calculate the time parameters:

- duration of any impulse of series

$$(t_i)_{li} = (t_{зi})_{li} - (t_{ni})_{li}, \tag{3}$$

- the duration of the actual series

$$t_{i\Sigma} = \sum_{li=1}^{N_{i.u}} \left(t_i\right)_{li} . \quad (4)$$

The proposed means for measuring control detects and fixes impulse deviations from sinusoidal form of network voltage.

After this, the following signal processing is possible: data accumulation, overvoltage settings fixation, the formation and transmission of a control signal to the protective devices and switching, etc.

Application of the obtained parameters is possible, for example, by the developed mathematical model of thermal balance [12]. This makes it possible to calculate the heating processes of internal electrical wiring copper conductors of different cross-sections and that are laid in different ways in rooms to a set temperature. It also determines the heating time to a degree that can cause the ignition of insulating materials and building structures that are in contact with the conductor. This will allow detection of the minimum heating time to the critical temperature reading, as well as verify the parameters of the protection appliances in order to prevent overheating of the conductors by impulse surges.

IV. Conclusion

The arrangement of the lightning protection system depends on the assessment of risk, the owner's response, the influence of the control bodies. Therefore, it is important to make a decision on the use of protection measures in the procedures for assessing the risks of lightning. But it can also be taken regardless of the results of risk assessment where there is a desire to avoid unacceptable risk. One of the parameters in the formula for assessing the components of risk may be the value of the measured influence factor - overvoltage in the network.

Thus, in order to supplement the protection against direct lightning or voltage disturbances by the remote discharge provided for in Table I [1], it is necessary to choose the type of protective devices and the circuit of their installation recommended by international standards of the IEC [5]. Using the proposed structure of the instrument for measurement and control of pulsed surges will enable conducting in the required volume of research of processes of impulse distortions in power grids with the identification and elimination of the electricity quality deterioration causes. That substantially reduces the risk of fires and electronic device damage origin. This will help both increase the reliability of power systems and protect electronic and electrical equipment of different cost.

As a result of the conducted research, the following goals were achieved: the duration of the distortion impulse or their series was determined, instantaneous (maximum) amplitude values of the impulse overvoltage were established. Implementation in the field of operation and maintenance of electronic and telecommunication equipment is being proposed. In particular, the application of the proposed method and means in assessing the risk of economic loss from damage of such equipment. Measurement, parameter analysis and study of the impact of thunderstorm activity on IT, telecom devices was performed. Other non-security related applications possibility is being analyzed.

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